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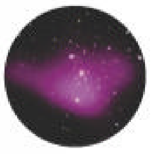
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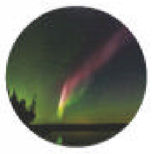
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As you read through this issue of **All About Space**, you'll notice there's something a little different. This month, we've launched our very own augmented reality (AR) experience, enhancing your journey through the universe with the aid of your smartphone. This issue - and for many editions to come - scan the QR code and you'll be able to play videos, see spacecraft in three dimensions as they leap off the page and much more. Turn to the contents page for a quick tutorial and look out for the 'AR' stamps as you move through the magazine.

This month we've got plenty to keep you entertained throughout lockdown - whether you're keeping out of the harsh wintry weather or have been gifted with crystal-clear skies for a spot of observing. Our cover feature assesses the chances of a space war - and whether planet Earth is really ready for a cosmic battle - before we head to nearby star system Proxima Centauri to investigate what could have caused a signal picked up by the Parkes Radio Telescope in Australia. We also uncover the truth about the different kinds of dark matter, the chances of being killed by a falling meteorite and provide details of the very best sights to observe without a telescope.

See you next time. I hope you enjoy your enhanced version of **All About Space** as much as we loved making it. Stay safe!

GEMMA LAVENDER

EDITOR-IN-CHIEF

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8 JANUARY 2021

Return to sender

This image captures the moment Northrop Grumman's Cygnus space freighter departed the International Space Station (ISS) after a lengthy three-month stay. Cygnus successfully delivered over 3,500 kilograms of scientific equipment and supplies while attached to Canadarm2, the ISS' robotic arm. Canadarm2 lends a helping hand to the Space Station by aiding in maintenance, moving supplies and 'catching' visiting vehicles.

The freighter was released from the robotic arm on 7 January 2021, but it wasn't sent away empty handed: the ISS crew loaded Cygnus with the Saffire-V investigation, the SharkSat-hosted payload, and a large amount of rubbish to be used in an extended mission in orbit. The junk safely burned up on re-entry.

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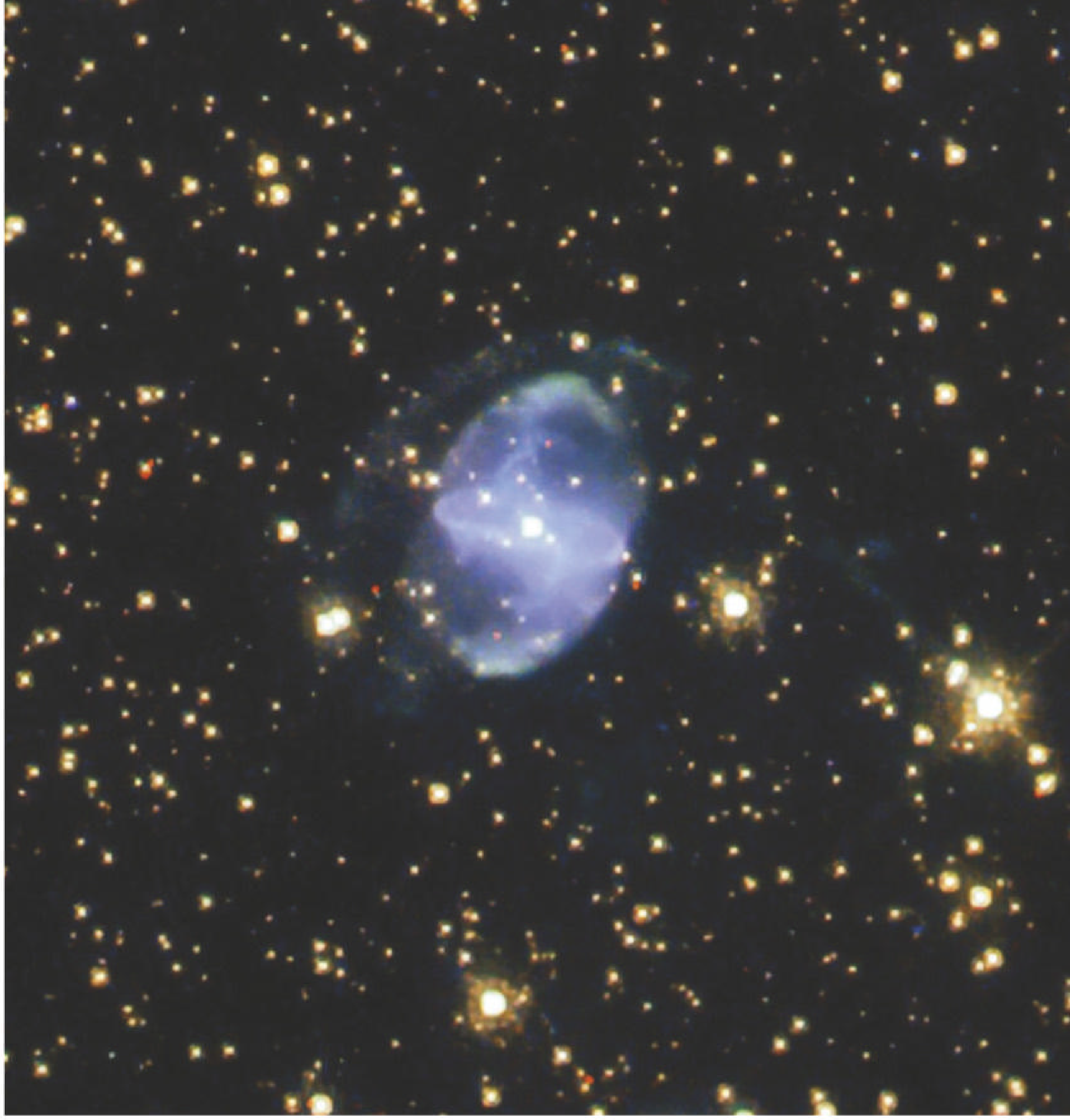
27 JANUARY 2021

Interstellar synergy

The chaotic nature of space is depicted in this image as the death of a star results in the scattering of material into the interstellar medium. This vast space between stars is anything but empty; it is filled with the relics of past supernovae, mainly gas and dust, albeit at very low densities. With time this medium will give rise to a new generation of stars.

NASA's Hubble Space Telescope captured this fascinating cosmic interaction, where the planetary nebula ESO 455-10 – located in the constellation of Scorpius – can be seen offloading an abundance of elements into its immediate surroundings.



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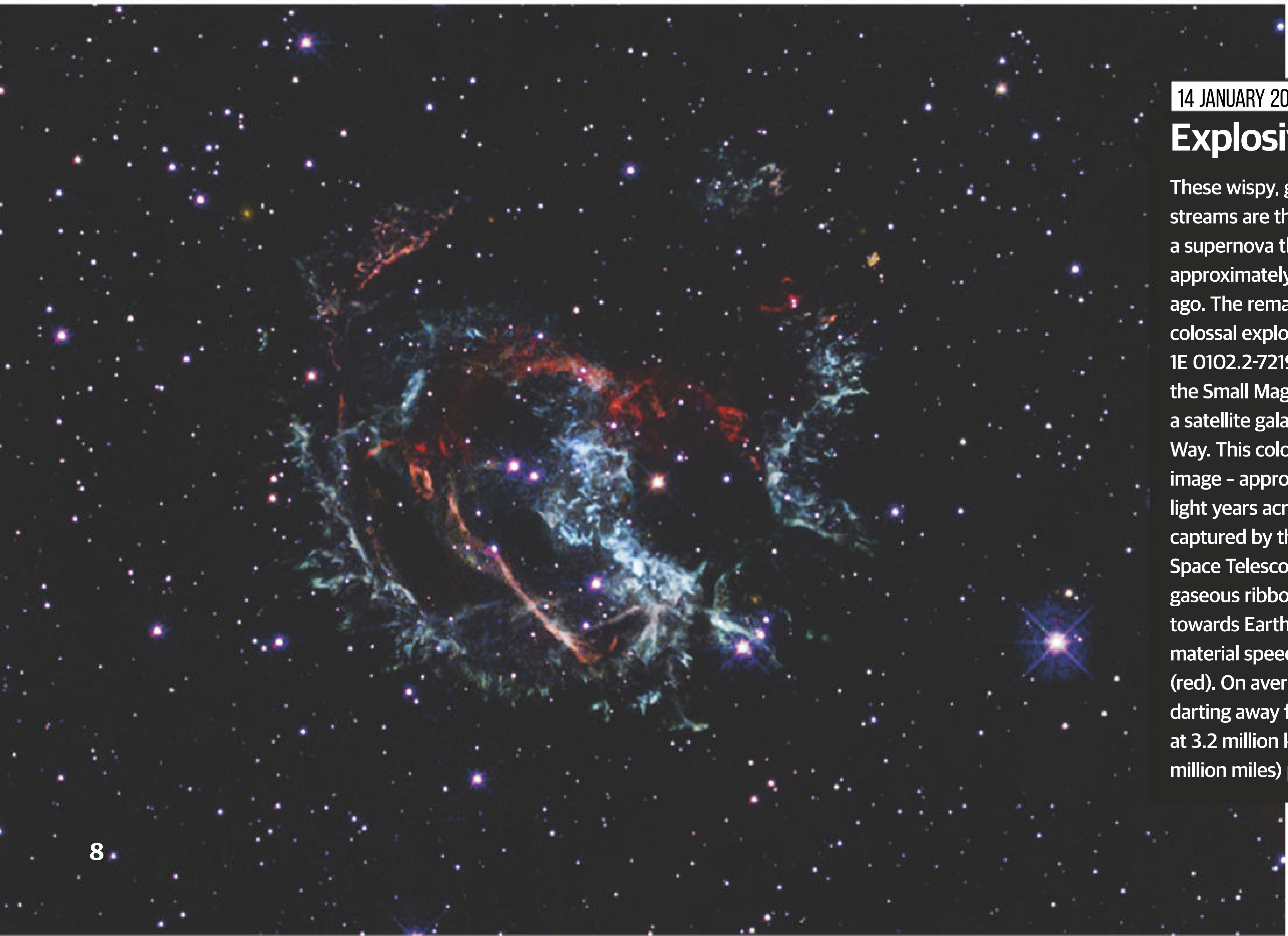

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Explosive relic

These wispy, gaseous streams are the remnants of a supernova that occurred approximately 1,700 years ago. The remains of this colossal explosion, named 1E 0102.2-7219, are found in the Small Magellanic Cloud, a satellite galaxy of the Milky Way. This colour-composite image – approximately 84 light years across – and captured by the Hubble Space Telescope shows gaseous ribbons moving towards Earth (blue), and material speeding away (red). On average, they're darting away from the centre at 3.2 million kilometres (2 million miles) per hour.

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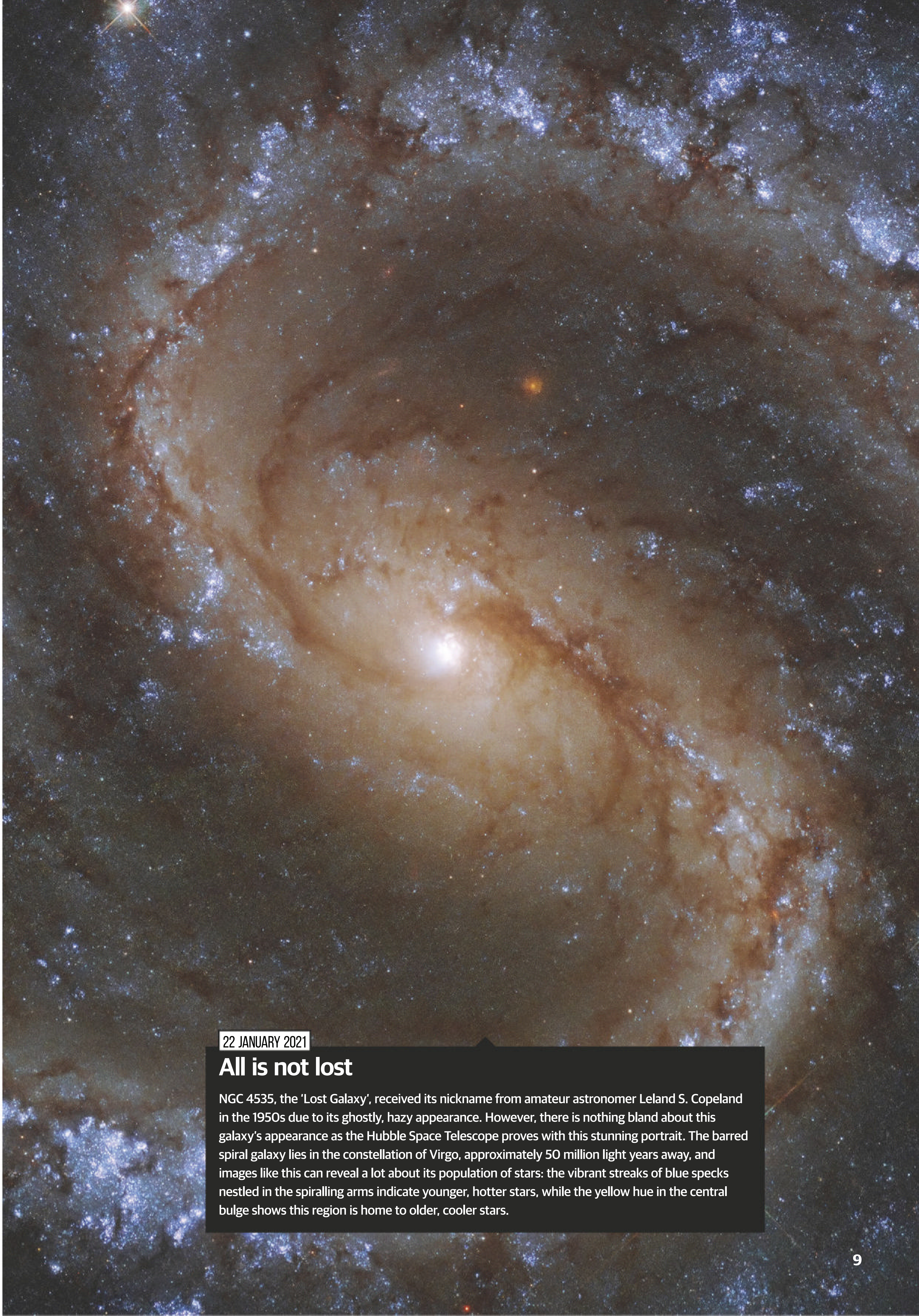

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All is not lost

NGC 4535, the 'Lost Galaxy', received its nickname from amateur astronomer Leland S. Copeland in the 1950s due to its ghostly, hazy appearance. However, there is nothing bland about this galaxy's appearance as the Hubble Space Telescope proves with this stunning portrait. The barred spiral galaxy lies in the constellation of Virgo, approximately 50 million light years away, and images like this can reveal a lot about its population of stars: the vibrant streaks of blue specks nestled in the spiralling arms indicate younger, hotter stars, while the yellow hue in the central bulge shows this region is home to older, cooler stars.

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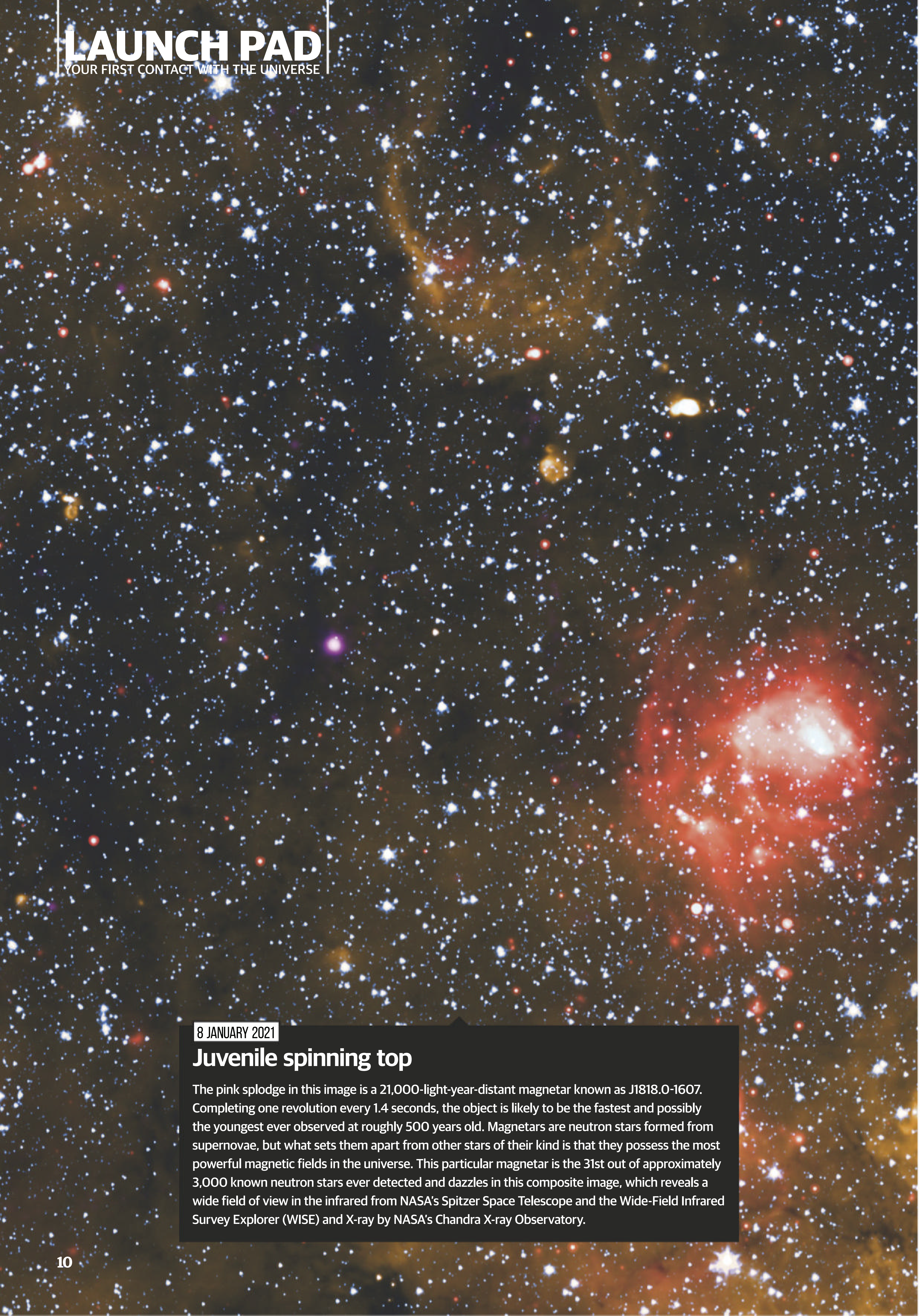

8 JANUARY 2021

Juvenile spinning top

The pink splodge in this image is a 21,000-light-year-distant magnetar known as J1818.0-1607. Completing one revolution every 1.4 seconds, the object is likely to be the fastest and possibly the youngest ever observed at roughly 500 years old. Magnetars are neutron stars formed from supernovae, but what sets them apart from other stars of their kind is that they possess the most powerful magnetic fields in the universe. This particular magnetar is the 31st out of approximately 3,000 known neutron stars ever detected and dazzles in this composite image, which reveals a wide field of view in the infrared from NASA's Spitzer Space Telescope and the Wide-Field Infrared Survey Explorer (WISE) and X-ray by NASA's Chandra X-ray Observatory.

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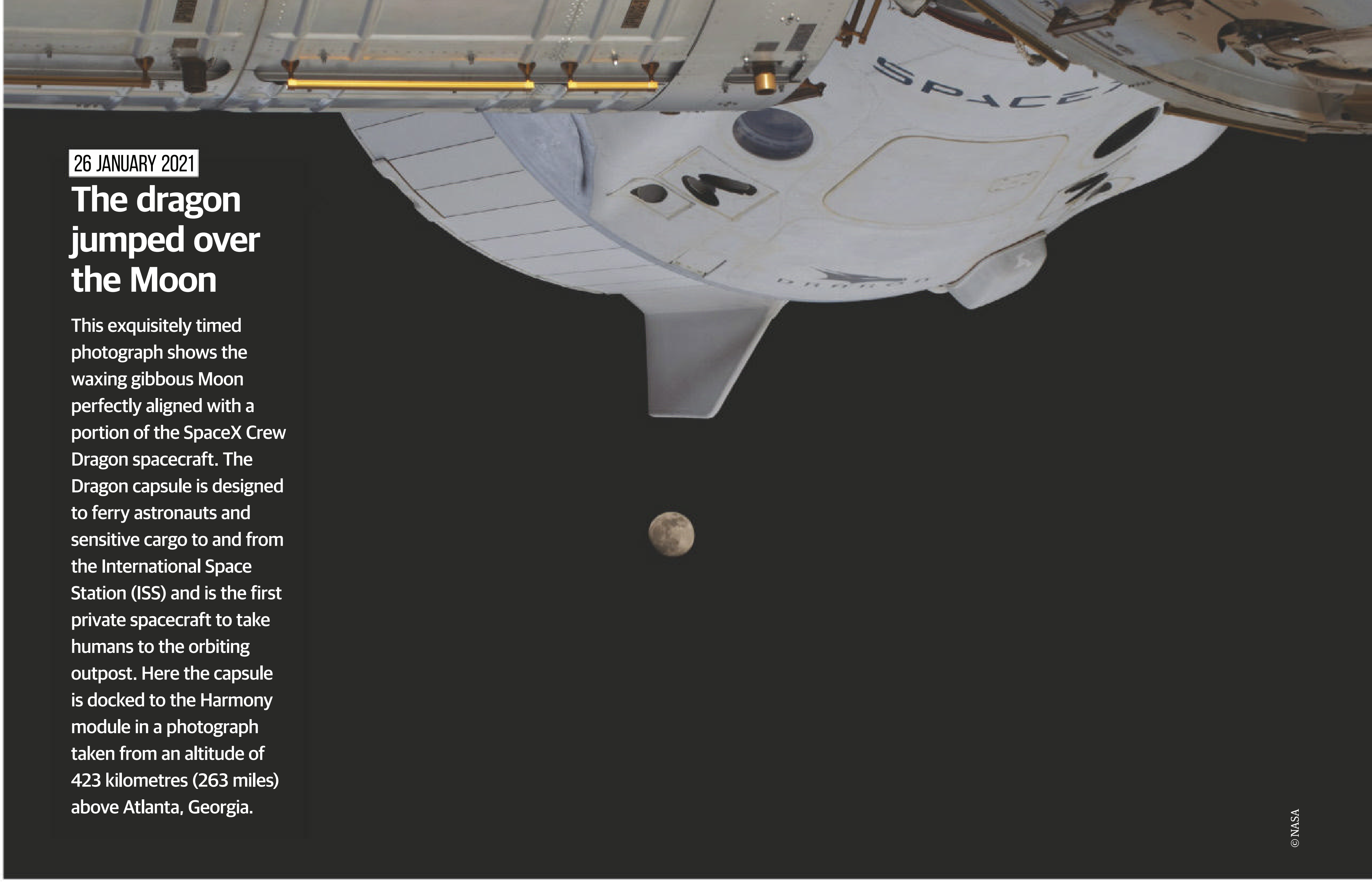

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The dragon jumped over the Moon

This exquisitely timed photograph shows the waxing gibbous Moon perfectly aligned with a portion of the SpaceX Crew Dragon spacecraft. The Dragon capsule is designed to ferry astronauts and sensitive cargo to and from the International Space Station (ISS) and is the first private spacecraft to take humans to the orbiting outpost. Here the capsule is docked to the Harmony module in a photograph taken from an altitude of 423 kilometres (263 miles) above Atlanta, Georgia.

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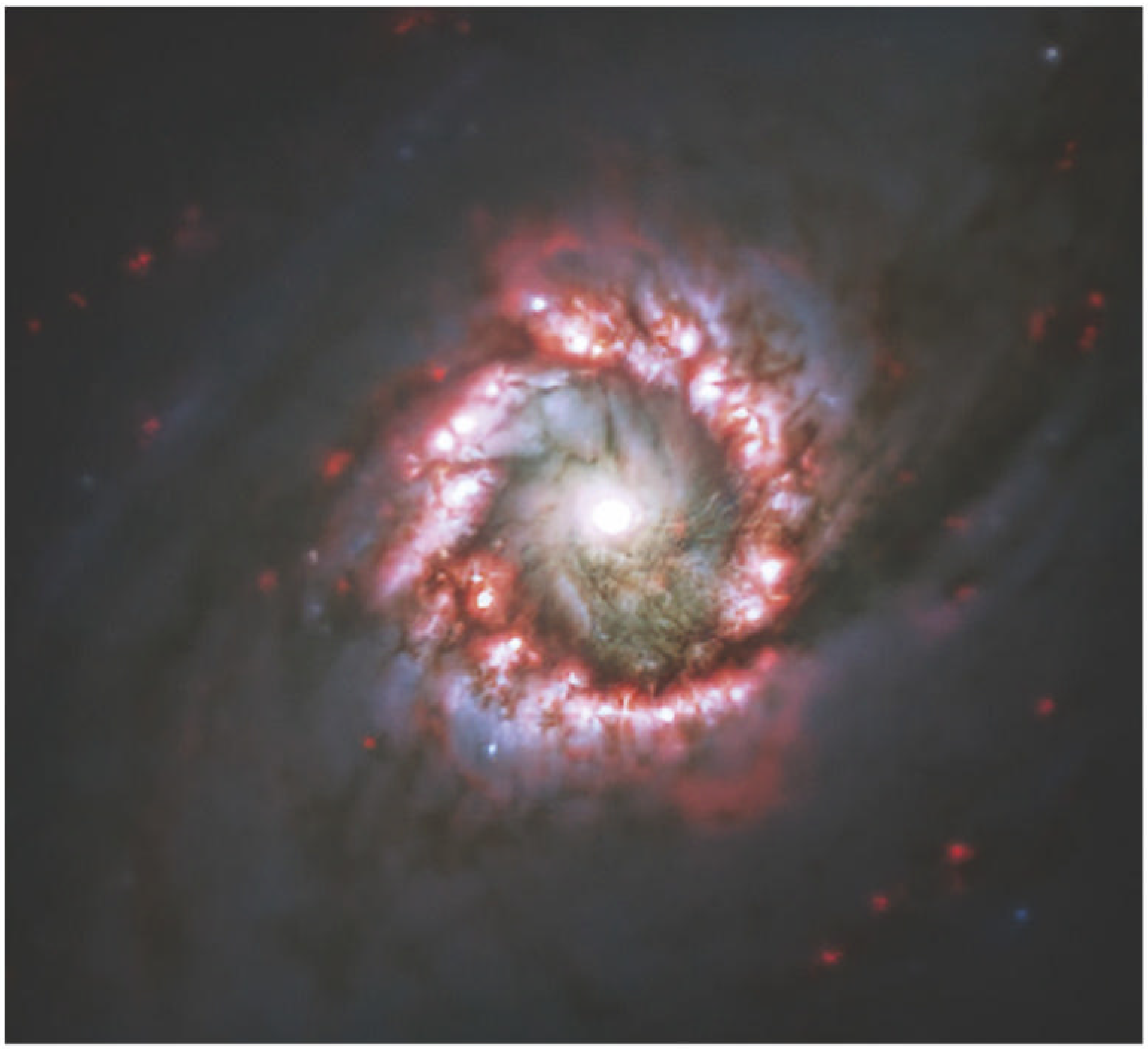

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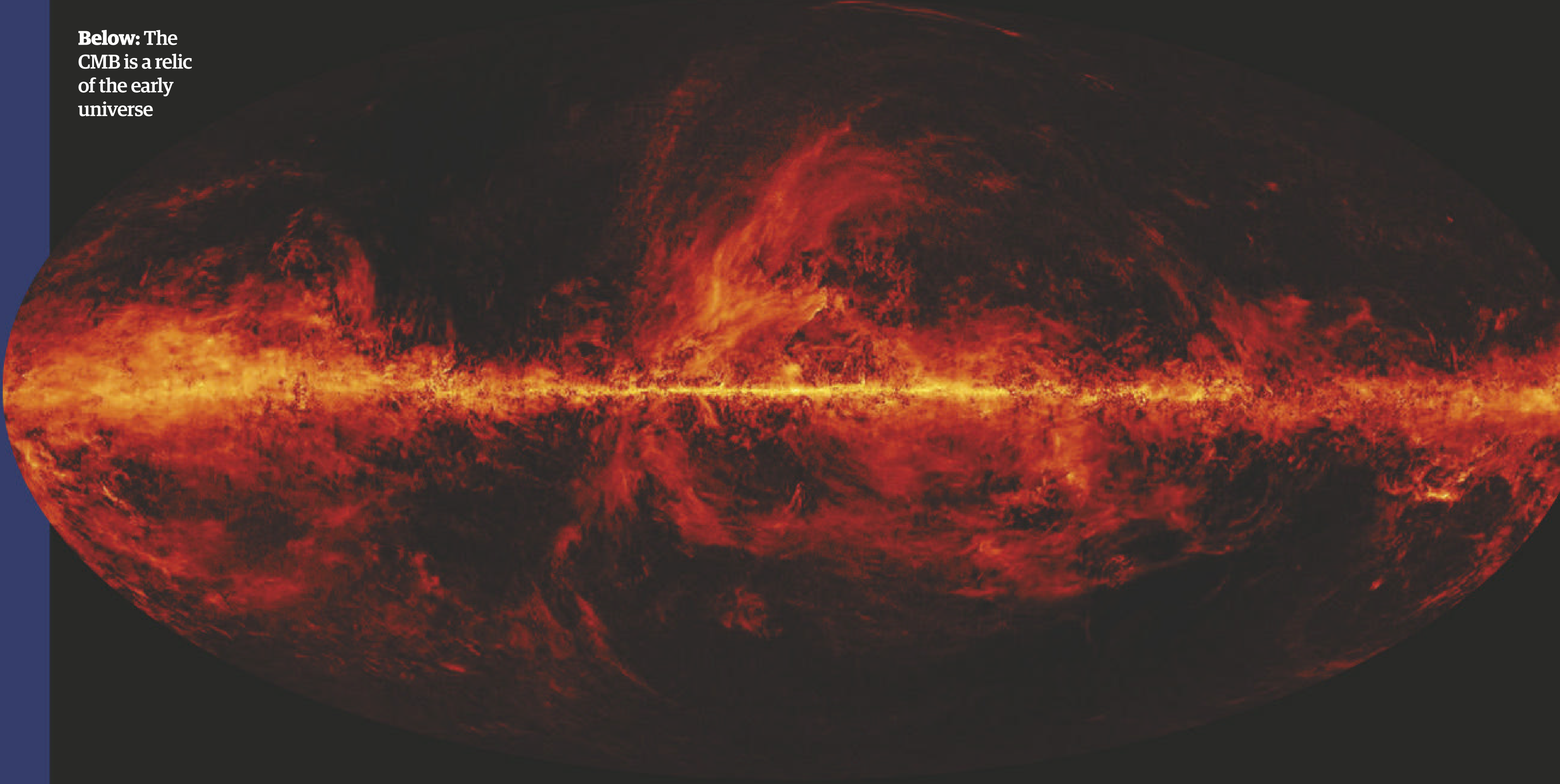
11 JANUARY 2021

Cosmic rose

At the heart of distant spiral galaxy NGC 1097 lies a supermassive black hole encompassed by a celestial soup of rapid star formation, located 45 million light years from Earth in the Fornax constellation. The rose-tinted accretion disc surrounding the supermassive black hole is a mere 5,000 light years across, overshadowed by its host galaxy, which extends for tens of thousands of light years beyond the centre. It was captured with the MUSE Multi Unit Spectroscopic Explorer (MUSE) instrument on the European Southern Observatory's Very Large Telescope in Chile.

Below: The CMB is a relic of the early universe



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Twisted space light could reveal brand-new physics

Words by Mara Johnson-Groh

A twist in the universe's first light could hint that scientists need to rethink physics. Two Japanese scientists looked at the polarisation, or orientation, of light from the cosmic microwave background radiation, some of the earliest light emitted after the universe's birth.

They found that the polarisation of photons, or light particles, might be slightly rotated from their original orientation when the light was first produced. And dark energy or dark matter may have been responsible for that rotation. Dark energy is a hypothetical force that is flinging the universe apart, while proposed dark matter is a substance that exerts gravitational pull, yet does not interact with light.

The rotated signature tells the scientists that something may have interacted with those photons - specifically something that violates a symmetry physicists call parity. This parity says that everything looks and behaves the same way, even in a flipped system - similar to how things look in the mirror. And if the system was following this parity rule, there wouldn't be this rotation change.

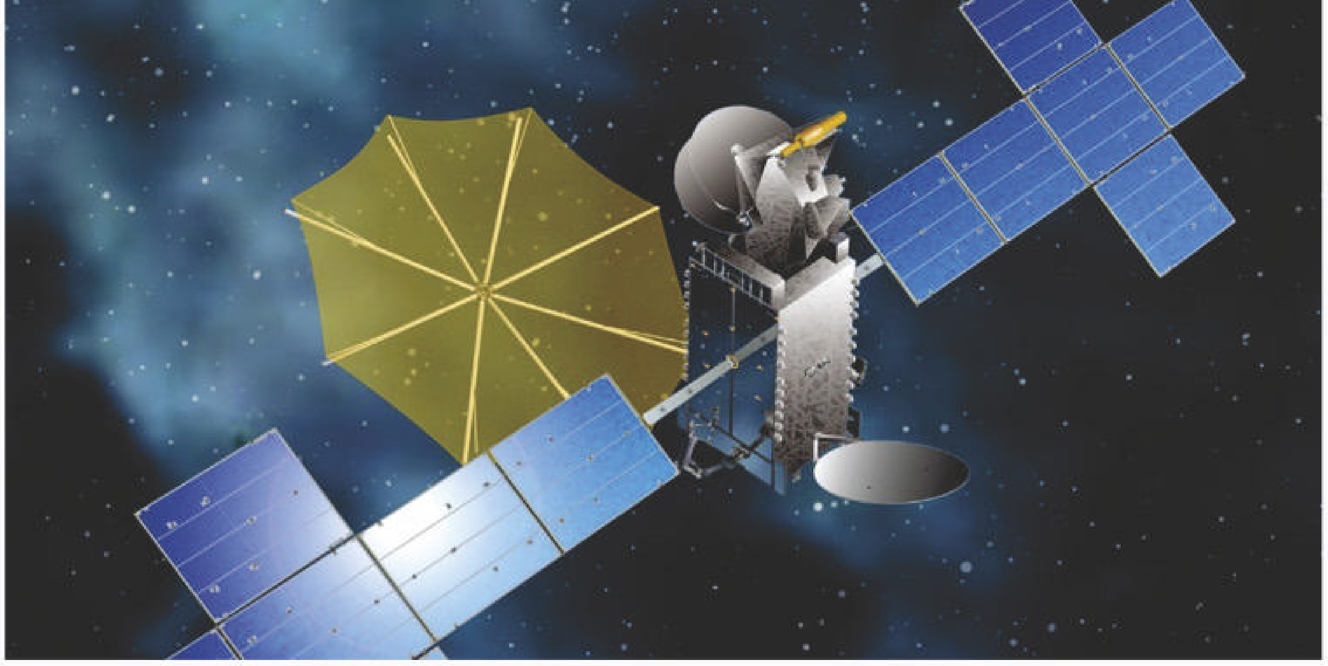
Parity is shown by all subatomic particles and all forces except the weak force. However, the new results suggest that whatever the early light might have interacted with might be violating this parity. "Maybe there is some unknown particle, which contributes to dark energy, that perhaps rotates the photon polarisation," said Yuto Minami, a physicist at the Institute of Particle and Nuclear Studies (IPNS) of the High Energy Accelerator Research Organization (KEK) in Japan.

When the cosmic microwave background radiation, or CMB, was first emitted 13.8 billion years ago, it was polarised in the same direction. Looking at how the light's polarisation has rotated over time allows scientists to probe the universe's history since that time by looking at how the light has changed as it travels across space and time.

Using the dusty Milky Way light, the scientists were able to figure out precisely how their instruments were oriented, so they knew the rotation in the light was real, not something caused by their instruments. This allowed them to determine the polarisation rotation of CMB light was non-zero, which means that the light has interacted with something that violates parity. It's possible something in the early universe affected the light, but it's more likely that it was something along the light's path as it travelled towards Earth. That something could be dark energy or dark matter, which would mean that the particles that make up these mysterious substances violate parity.

The researchers reported their findings with 99.2 per cent confidence, meaning there's an 8 in 1,000 chance of getting similar results by accident. However, this isn't quite as confident as physicists require for absolute proof. For that they need five sigma, or 99.99995 per cent confidence, which likely isn't possible with data from just one experiment. But future and existing experiments might be able to gather more accurate data, which could be calibrated with the new technique to reach a high enough level of confidence. "Our results do not mean a new discovery," Minami said. "Only that we found a hint of it."

> "MAYBE THERE IS SOME UNKNOWN PARTICLE, WHICH CONTRIBUTES TO DARK ENERGY, THAT PERHAPS ROTATES THE PHOTON POLARISATION"



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Above: It's not currently known what caused the failure

Broadcaster's satellite fails in orbit

Words by Amy Thompson

SiriusXM's newest satellite, SXM-7, has suffered undisclosed failures during in-orbit testing, the company revealed in a filing with the US Securities and Exchange Commission on 27 January. "During in-orbit testing of SXM-7, events occurred which have caused the failure of certain SXM-7 payload units. An evaluation of SXM-7 is underway. The full extent of the damage to SXM-7 is not yet known," SiriusXM said in the filing. At this time, it's unclear if the satellite can be recovered.

The satellite, which was built by Maxar Technologies, launched on a SpaceX Falcon 9 rocket on 13 December. The company has said the failure was unrelated to the launch vehicle and that a full evaluation of the satellite is underway.

The SXM-7 satellite is based on Maxar Technologies' SSL 1300 satellite bus. Powered by two large solar arrays and batteries for storage, it was designed to operate in the S-band spectrum, between 2.32 and 2.345 GHz. The satellite is part of a pair that Maxar built and SpaceX is launching for SiriusXM. The other, SXM-8, is still under construction and set to launch later this year. Each satellite has an operational lifetime of 15 years, and were intended to replace two aging satellites already in orbit. The satellites are designed to support SiriusXM's digital radio service, providing coverage across the US, Canada and the Caribbean.

SXM-7 began its in-orbit testing phase on 4 January, which is a normal shakedown phase before a satellite enters service. The testing typically lasts for a few months. The company has yet to determine what went wrong, but says it is in control of the satellite.

OSIRIS-REx to leave asteroid in May to deliver samples

Words by Mike Wall

NASA's asteroid-sampling OSIRIS-REx probe will spend two extra months at its target space rock before heading back to Earth. OSIRIS-REx snagged lots of dirt and rock from the 1,640-foot (500-metre) wide near-Earth asteroid Bennu in October 2020 - so much stuff, in fact, that the probe's sample collector was overflowing.

The original mission plan called for OSIRIS-REx to leave Bennu's vicinity with this precious cargo on 3 March. But the departure date has been pushed back to 10 May, NASA officials announced on Tuesday 26 January. "Leaving Bennu's vicinity in May puts us in the 'sweet spot,' when the departure manoeuvre will consume the least amount of the spacecraft's onboard fuel," said Michael Moreau, OSIRIS-REx deputy project manager at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "Nevertheless, with over 954 kilometres (593 miles) per hour of velocity change, this will be the largest propulsive manoeuvre conducted by OSIRIS-REx since the approach to Bennu in October 2018," Moreau added.

The new plan doesn't change the arrival time for the Bennu samples. They're still scheduled to come down to Earth, in a special return capsule, in northern Utah on 24 September 2023. That touchdown will complete a recent sample-return trifecta for humanity: pristine samples from the Moon and the asteroid Ryugu came down to Earth last month courtesy of China's Chang'e 5 mission and Japan's Hayabusa2 probe, respectively.

© NASA

Left: Bennu was discovered in 1999, it later became a target for NASA

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Extreme black holes probably have 'hair'

Words by Mike Wall

Black holes may not be so simple after all. According to a leading idea known as the 'no-hair' or 'black hole uniqueness' theorem, black holes can be fully characterised using just three data points - their mass, spin and electric charge. There's no other observable information to be had about these light-gobbling behemoths, which therefore seem to be sleekly and uniquely 'bald'. But new research casts doubt on the no-hair idea, or at least its universal application: computer simulations suggest that 'extreme' black holes - the ones whose spin or electrical charge is fully maxed out - do sport a few wispy hairs here and there.

"This new result is surprising because the black hole uniqueness theorems are well established, [as is] their extension to extreme black holes," said Lior Burko of Theiss Research in La Jolla, California. "There has to be an assumption of the theorems that are not satisfied to explain how the theorems do not apply in this case."

The inferred black-hole hairs manifest as a quantity that can be constructed from the space-time curvature at the black hole horizon that is conserved, and measurable by a distant observer. This quantity depends on details of the black hole's formation, so it goes beyond the bare-bones trio of mass, spin and charge. Excitingly, such hairs may not remain purely theoretical forever. Scientists might be able to spot them using gravitational-wave detectors such as the Laser Interferometer Gravitational-Wave Observatory (LIGO).

© NASA/JPL-Caltech

Above: Black holes still have many secrets left to spill

Students help discover four new planets

Words by Mike Wall

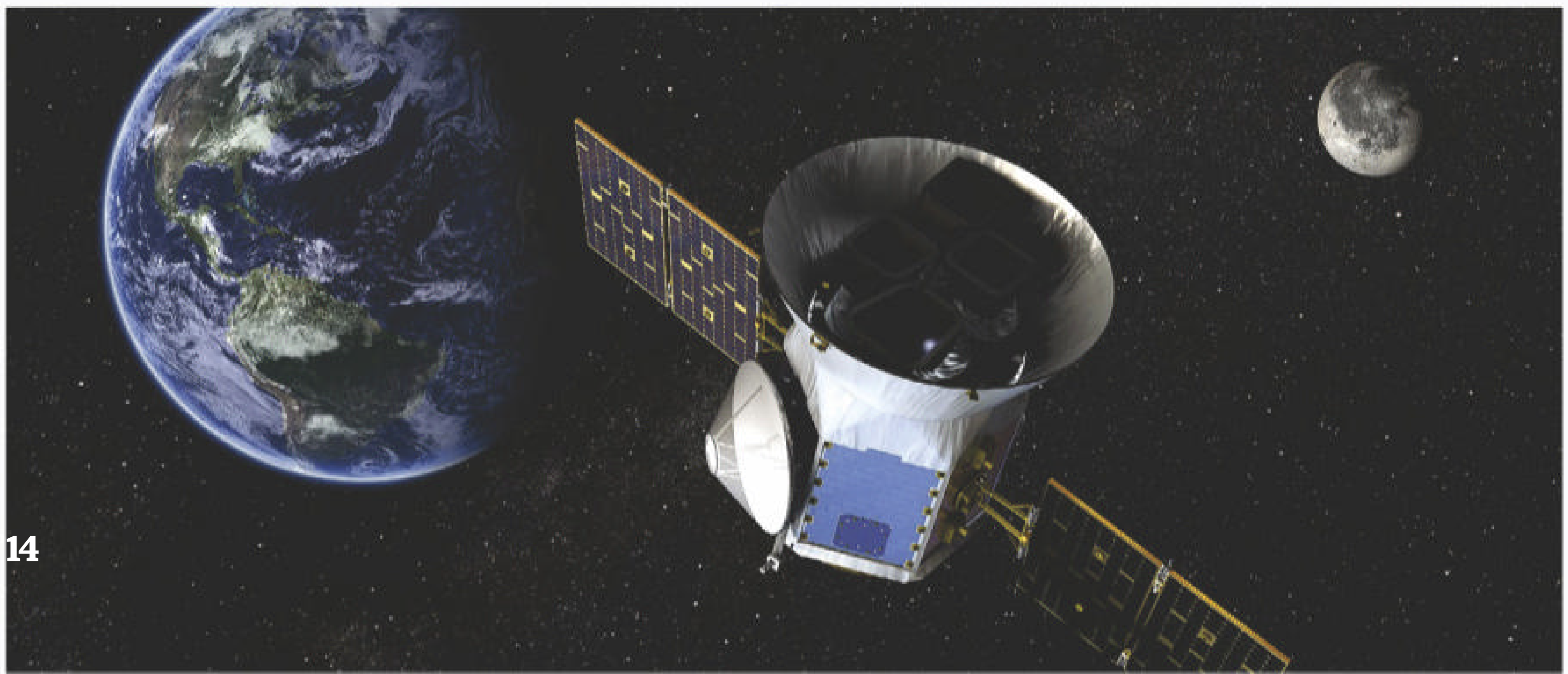
Two Massachusetts school students - 16-year-old Kartik Pinglé and 18-year-old Jasmine Wright - have helped discover four new alien planets. Pinglé and Wright did their otherworldly work via the Student Research Mentoring Program (SRMP) at the Harvard-Smithsonian Center for Astrophysics and the Massachusetts Institute of Technology (MIT), which links up local high-school students with scientists for year-long projects. "By the end of the program, the students can say they've done active, state-of-the-art research in astrophysics," SRMP director Clara Sousa-Silva, a quantum astrochemist at MIT, said.

Pinglé and Wright worked with Tansu Daylan, a postdoctoral researcher at MIT's Kavli Institute for Astrophysics and Space Research. Daylan and his colleagues scrutinised observations of the Sun-like star HD 108236 made by NASA's Transiting Exoplanet Survey Satellite (TESS). TESS hunts for alien worlds via the transit method, noting the tiny but telltale dips in stars' brightness caused when orbiting planets cross their faces from the spacecraft's perspective.

The team confirmed four such planet-caused dips in the light curve of HD 108236, which lies about 200 light years from Earth. "I was very excited and very shocked," Wright said. "We knew this was the goal of Daylan's research, but to actually find a multi-planetary system, and be part of the discovering team, was really cool."

Three of the four newfound worlds are gaseous planets slightly smaller than Neptune. The fourth is a super-Earth, a rocky planet a bit larger than our own, the researchers said. All four exoplanets lie very close to HD 108236; their orbital periods range from just under four Earth days to 19.5 Earth days.

Below: TESS has been studying the stars since 2018



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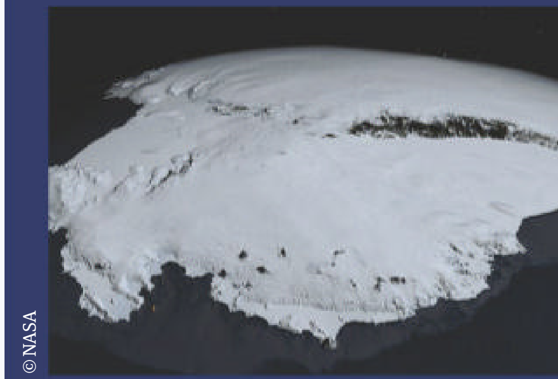
Martian mineral found in Antarctic ice

Words by Nicoletta Lanese

Scientists boring into ice have unearthed a mineral that's rarely seen on Earth but found in abundance on Mars. The yellow-brown mineral, jarosite, requires both water and acidic conditions to form - environments that are hard to find now on the Red Planet. After the Opportunity rover first discovered jarosite on Mars in 2004, the mineral turned up in several Martian locations, leaving scientists wondering how it had become so common.

Some theorised that when ice covered the planet billions of years ago, dust containing the required minerals - iron, sulphate and potassium - may have been trapped inside. "Mars is such a dusty place - everything is covered in dust," said Giovanni Baccolo, a geologist at the University of Milan-Bicocca. But while ice could have provided the wet environment needed for acidic dust to transform into jarosite, scientists have never actually seen dust and ice chemically reacting to form the mineral. But the discovery of jarosite particles locked in Antarctica's ice may support the theory.

Slabs of jarosite may have formed on Mars because the Red Planet is far dustier than Antarctica, providing more raw material to form jarosite.



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Right: Antartica is a hotspot for finding asteroids - and now jarosite

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SPACE WARS

IS PLANET EARTH READY FOR A COSMIC BATTLEGROUND?

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SEVERAL COUNTRIES ARE SPENDING A LOT MORE ON MILITARY SPACE, WORRYING PEACEMAKERS

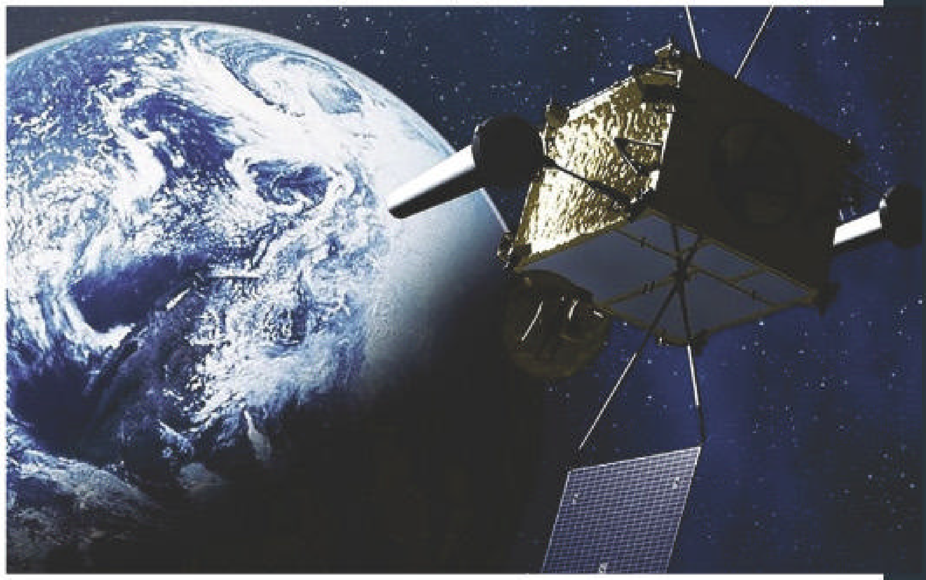
Reported by Ian Parker

Years ago, Buzz Aldrin said: "Once you have stood on another celestial body and looked back at the Earth, you realise how small, precious and fragile it is amid the vastness of space. We shouldn't be fighting over it." Buzz was a successful fighter pilot before he became an astronaut, and the experience of walking on the Moon changed him hugely. The moonwalkers went there in peace for all humankind. If NASA plans work out, they will do it again.

Most have always had philosophies and feelings which transcend national, cultural and racial barriers. It comes with the turf. Space agencies around the world, including NASA and the European Space Agency (ESA), are for the peaceful exploration of space. But for others, 'peaceful' equates with 'defence', since strong armed forces can keep the peace. Military planners in the richer nations are increasingly turning their attention to space for the protection of space assets and services and possible warfighting in orbit. Developments in civil space can often be applied to military programs.

Recent, very worrying political events have shown that even the most developed and trusted political systems are failing to prevent megalomaniacs from gaining power. And these people are often in charge of the armed forces. If the bad are strong, then the good must be stronger. But this can often lead to the proliferation of arms and a strengthening of the military-industrial machine where manufacturers make a huge amount of money out of arms contracts, therefore influencing politicians to support military spending. At one point the US had some 31,000 nuclear warheads, and you might wonder how many planets they were planning to destroy with those.

As far as we know, no country has ever put a nuclear warhead in space, as it was banned by international agreement decades ago - it probably isn't that advantageous anyway. It may seem strategic to put them in geostationary orbit, 36,000 kilometres (22,370 miles) above a likely enemy, but it's better to keep them on rockets in underground silos because they need servicing. Even if an intercontinental ballistic missile (ICBM) has to fly halfway around the world to attack an enemy, it's still a shorter distance than flying down from geostationary orbit.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Left: Skynet 6 is the UK's next military communications satellite

Destroying a satellite with a bomb or even just an impact has been demonstrated, but it's very expensive - and it might miss. A large number of conventional missiles simply miss their targets, even if the target isn't being evasive. It's far better to attack satellites by uploading debilitating data or with lasers, both from the ground or other spacecraft. Alternatively, the services they provide can be attacked. For example, the GPS signal at ground level is quite weak, and it doesn't take much to scramble or spoof it. It can't be easily strengthened because of the altitude of the satellites and their limited solar panels.

Military operations are now increasingly dependent on space assets, particularly for communications, navigation and Earth observation. No force wants to end up cut off, lost and blind, so nations are becoming increasingly defensive of their satellites and the services they provide.

On 20 December 2019, the US Space Force was established as an independent military branch with the signing of the United States Space Force Act, part of the National Defense Authorization Act for 2020. Space Force consists of about 16,000 personnel, and operates 77 spacecraft, including the Boeing X-37B space planes and the Global Positioning System (GPS). The Space Force is to “provide freedom of operation for the United States in, from and to space” and “provide prompt and sustained space operations” to “protect the interests of the United States in space, deter aggression in, from and to space and conduct space operations.”

On 10 August 2020, the Space Force published its *Spacepower: Doctrine for Space Forces*, further expanding on its missions and duties. It defines three cornerstone responsibilities, explaining why space power is vital to US prosperity and security. It's partnered with the US Air Force, the National Reconnaissance Office and NASA, and is headed by General John W. Raymond.

The X-37B and its low-profile missions represent a significant US orbital asset. The fifth and latest mission, USA-277, was launched on 7 September 2017, and was the longest X-37 mission to date, landing on 27 October 2019 after 780 days in orbit. Former President Trump said: “Space is a war-fighting domain, just like the land, air and sea.”

THE INTERNATIONAL SPACE STATION: USING SPACE FOR HUMANKIND

CUPOLA

Agency esa **Country**

An observatory module whose seven windows are used to conduct experiments, watch dockings and make observations of Earth – it provides spectacular views.

COLUMBUS

Agency esa **Country**

Europe's largest contribution, it allows research to be carried out in a weightless environment and outside in space thanks to four exterior mounting platforms.

ZVEZDA

Agency **Country**

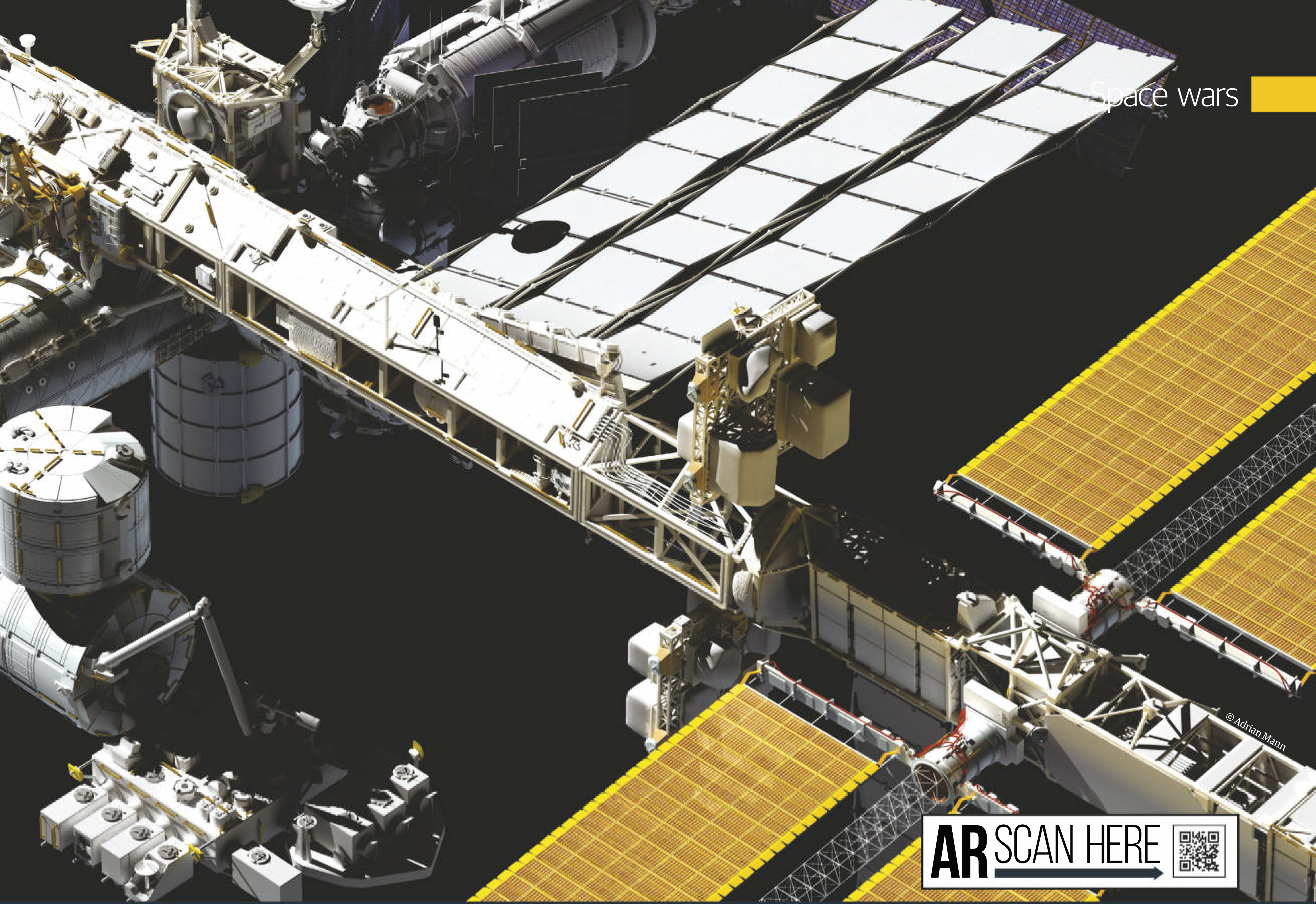
The first fully Russian module provides living quarters, life-support systems, electrical power distribution and data-processing, flight-control and propulsion systems.

Although NASA is a civilian organisation, its developments are closely watched by the military. On 16 January it conducted a hot fire test of the engines for its Space Launch System (SLS). The test was cut short after a parameter in the hydraulics system for gimballing was exceeded. But as the SLS components are being developed from Space Shuttle elements, development risk is reduced.

The test should have lasted eight minutes, but it was stopped after just 67 seconds. However, during the test, the four RS-25 engines, which are developed from Space Shuttle main engines, produced 725 tonnes of thrust, so it will be the most powerful launch vehicle ever made. “Seeing all four engines ignite for the first time during the core stage hot fire test was a big milestone for the Space Launch System team,” said John Honeycutt, the SLS program manager at NASA's Marshall Space Flight Center in Huntsville, Alabama. “We will analyse the data, and what we learned from today's test will help us plan the right path forward for verifying this new core stage is ready for flight on the Artemis I mission.”

Long-term space industry commentators have often said that NASA should never have scrapped the Saturn V rocket, which sent Apollo astronauts to the Moon, and now NASA is getting that capability back. No doubt this will be of great interest to the US Department of Defense, which will be calculating what payload masses it can put into Earth orbit with the SLS.

In early 2019, France unveiled work on a hypersonic glide vehicle (HGV), shortly before the country detailed its first defence space strategy.



© Adrian Mann

KIBO

Agency **Country** 🇯🇵

Kibo, which means 'hope', is Japan's first human space facility. Experiments on board focus on space medicine, biology, Earth observations, material production and communications research.

ZARYA

Agency **Country** 🇺🇸

The first component launched, Zarya was US-funded and Russian-built. It provided electrical power, storage, propulsion and guidance to the ISS during the initial stages of assembly.

UNITY

Agency **Country** 🇺🇸

Unity was the first piece of the ISS provided by the US. It was launched on the US Space Shuttle Endeavour in 1998, which was able to capture the previously launched Zarya and mate them together.

DESTINY

Agency **Country** 🇺🇸

The primary research lab for the US, it supports a wide range of experiments and studies in medicine, engineering, biotechnology, physics, materials science and Earth science.

LEONARDO PERMANENT MULTIPURPOSE MODULE (PMM)

Agency **Country** 🇮🇹

PMM is a large, reusable, pressurised element that was originally used to ferry cargo back and forth to the station. It has an end cone that has additional storage space.

France wants to sustain its 'strategic autonomy' in threat awareness, nuclear capabilities and emerging technologies, and its Air Force is becoming its Air and Space Force.

On 25 July 2019, Florence Parly, the Armed Forces minister, announced the space strategy, which included the possible weaponisation of satellites for self-defence. In 2018 France accused Russia of on-orbit espionage of a Franco-Italian military satellite. France wants better situational awareness in space and improved protection of key national and European space assets, including onboard lasers for satellite defence, all of which will boost the European space industry.

Support of France's nuclear deterrent is thought to be behind its Véhicule Manoeuvrant Experimental (V-MaX) project to develop a Mach

WHAT IS THE SPACE FORCE?

SPACE DOMAIN AWARENESS

Space Force will track and monitor satellites in orbit and try to make sure they are not at risk of colliding with any others, which in turn will reduce more space debris being created in collisions.

COMMAND AND CONTROL OF SATELLITE OPERATIONS

Assets like GPS will be looked after by the Space Force to make sure that the US doesn't lose access to any important space capabilities that are already in place.

MISSILE WARNING

The Space Force will continue developing satellites to monitor any missile launches that might threaten the US, its forces deployed around the world or any of its allies.

SPACE SUPPORT TO OPERATIONS

This includes making sure that military services on the ground that rely on space-based capabilities, such as satellites, are not interrupted and can continue operating with no issues.

SPACE SUPERIORITY

Space Force is designed to make sure the US remains a leader in all space activities. This means having continuing access to space, including the launch and operation of satellites.

THE ROAD TO SPACE WARFARE

No battles have been fought in space so far, and many bodies want to prevent it

1950s

NIKE-ZEUS, DEFENDER AND SENTINEL

In the late 1950s, the US started missile programs to defend against Soviet ICBMs, blowing them up in space with nuclear warheads.

1955

US AIR FORCE ORDERS SPY SATELLITES

These include nuclear explosion detection and electronic, optical and radar imaging surveillance, later including the KH-11 series.

1958

PROJECT A119

The US Air Force developed a plan to explode an atomic bomb on the Moon to demonstrate superiority.

1962

THE FIRST KOSMOS WAS LAUNCHED

Almost all Soviet and Russian military satellites have this designation, mostly for communications and surveillance.

1969

SKYNET 1 LAUNCHED

The UK's current military communications satellite is Skynet 5, with Skynet 6 due for launch in 2025.

1983

HOMING OVERLAY EXPERIMENT

The US Army destroyed incoming mock ICBM warheads with a kinetic kill vehicle (KKV).

5-plus HGV. The nation aims to fly a demonstrator this year. HGVs can be effective against an enemy's missiles. Until recently, satellite threat assessment focused on ground-based risks, such as communications jamming, cyber attacks, the use of lasers to dazzle or damage satellite sensors or missile interceptors. Growing concerns about on-orbit threats, however, have prompted Paris to consider passive and active protection for its future satellites. As well as lasers, the defence ministry is looking at the use of onboard cameras to provide 'perimeter' warning of an approaching satellite that could be a threat. The threatened satellite could be manoeuvred out of the way.

The ministry is also looking at very small nanosatellites for a range of military roles. These would provide responsive access to space, and the capacity to rapidly reconstitute space-based intelligence, surveillance and reconnaissance (ISR) or communications were the existing satellites to be damaged or destroyed. The ability to quickly launch a replacement capability based on small or nanosatellites would provide resilience to attacks.

Announced last November, the UK Ministry of Defence (MoD) will receive an additional £16.5 billion ($22.6 billion) over the next four years in the biggest hike in spending in more than 30 years. Prime Minister Boris Johnson has outlined an upgrade of all of the UK's vital defences - which includes the creation of the first agency dedicated to artificial intelligence and satellites.

The investment also aims to create a space command capable of launching a UK rocket by 2022. Johnson stressed the need for extra resources for defence, despite the ongoing economic crisis caused by the coronavirus pandemic. He explained that the largest investment since the Cold War will "end the era of retreat" and "transform our armed forces". "I have taken this decision in the teeth of the pandemic because the defence of the realm must come first," he stated. Defence Secretary Ben Wallace said the UK would be spending £400 million ($547 million) more on projects in space: "On space we already spend a considerable sum, and the extra is to take us to the next stage."

Perhaps surprisingly, Russia seems to be behind on military space since it started the Space Race in the late 1950s with the launch of Sputnik, the world's first artificial satellite. It is working to expand its anti-access/area-denial approach to space in the form of electronic warfare, increasing sustainability of its communication systems and developing offensive capabilities against ground-based space infrastructure.

Below: A rocket's power can be used to explore or to explode

© NASA

APRIL 2015

RUSSIA WORRIES INTELSAT

Russia puts its Luch (Olymp) satellite between Intelsats 7 and 901, which are very close.

AUGUST 2015

RUSSIAN SPACE FORCES ARE RE-ESTABLISHED

They operate GLONASS and the Persona reconnaissance satellites.

JULY 2019

FRANCE ANNOUNCES NEW SPACE DEFENCE STRATEGY

This includes the weaponisation of satellites with lasers and maybe explosives.

DECEMBER 2019

US SPACE FORCE ESTABLISHED

Former president Donald Trump makes it an independent military branch.

WHAT WEAPONS WILL BE USED?

1 Missiles

Missiles launched from the ground or aircraft can blow up satellites, but it's a very expensive and uncertain way of attacking them. Many satellites are in geostationary orbit, 36,000 kilometres (22,370 miles) up – a very long way for a missile to fly.

2 Lasers

Powerful lasers can blind or even destroy satellites, and they can be shone from the ground or other satellites. Satellites may also be able to fire lasers to destroy things on Earth.

3 Rods from space

Satellites equipped with metal rods – likely made from tungsten – could fire these at high speeds and angles. The kinetic energy would be the destructive force, with no need for explosives.

4 High-velocity particle beams

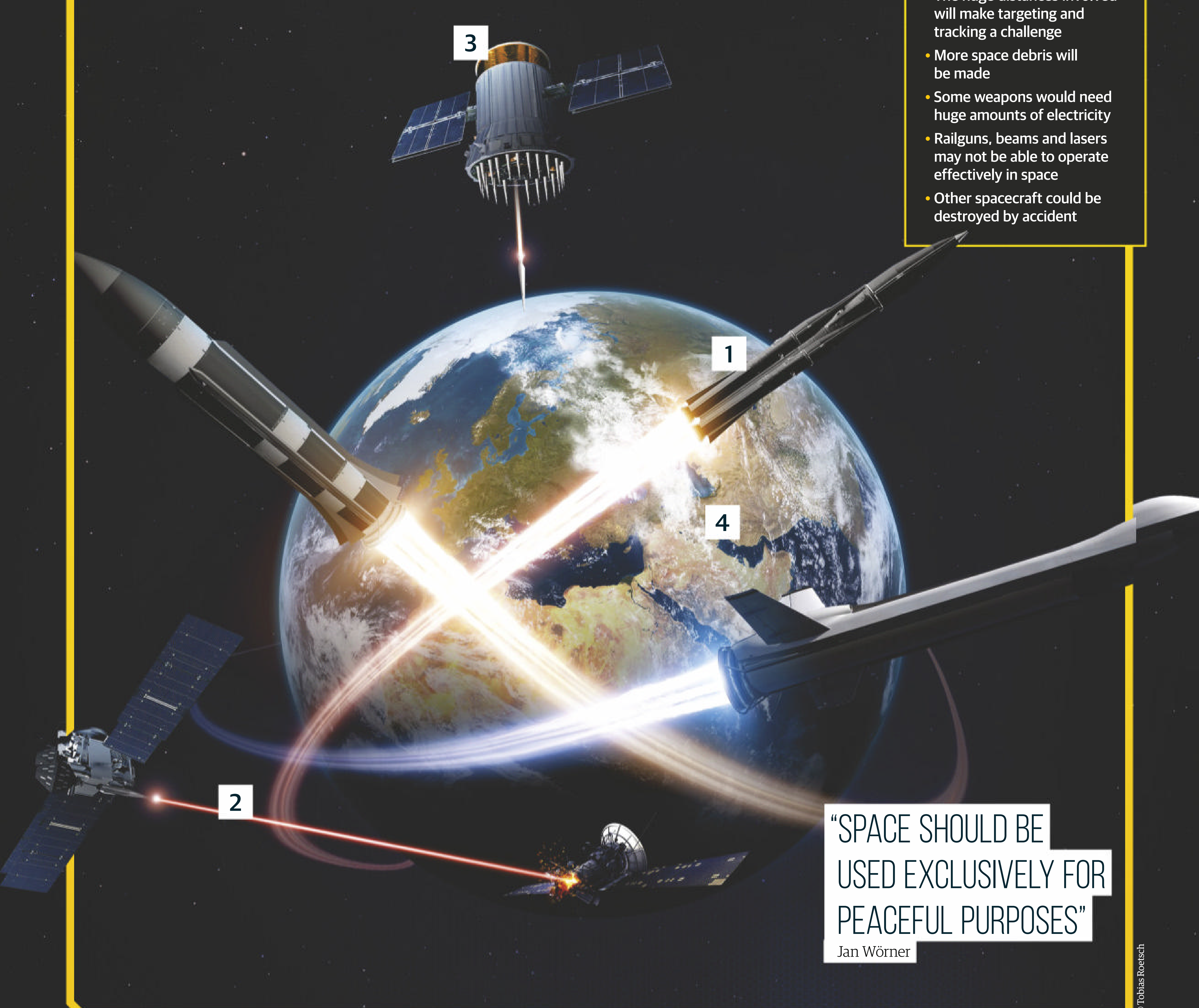
Intense beams of low-mass, high-energy particles could damage targets by disrupting their atomic structure. This deadly form of weapon is still in the research stage and may not be practical.

WHAT NEEDS TO BE CONSIDERED BEFORE WAR?

Spacecraft are already used a great deal in war for communications, surveillance and navigation. But enemies destroying satellites of other nations is a bold new step.

CONSIDERATIONS

- The huge distances involved will make targeting and tracking a challenge
- More space debris will be made
- Some weapons would need huge amounts of electricity
- Railguns, beams and lasers may not be able to operate effectively in space
- Other spacecraft could be destroyed by accident



> "SPACE SHOULD BE USED EXCLUSIVELY FOR PEACEFUL PURPOSES"
>
> Jan Wörner

© Tobias Roetsch

© Getty

Above: A military satellite could attack another with a laser

> “ON SPACE WE ALREADY SPEND A CONSIDERABLE SUM, AND THE EXTRA IS TO TAKE US TO THE NEXT STAGE”
>
> BEN WALLACE

According to the Union of Concerned Scientists, a US nonprofit organisation founded more than 50 years ago by scientists and students at the Massachusetts Institute of Technology, Russia has more than 170 satellites in orbit, of which about 100 are military. Using data from Russia's space agency Roscosmos, it's estimated that annual spending on the development of Russia's military satellite constellation – satellites, launch vehicles and launches – is $1 billion (£730 million). Spending on the Russian space navigation system GLONASS, currently made up of 27 satellites, in 2019 was $437 million (£319 million), and spending on the military launch site at Plesetsk Cosmodrome is at least $100 million (£73 million) annually.

All of these efforts, plus the cost of maintenance for other ground-based defence space infrastructure and personnel, means that Russia's military space program is about $1.6 billion (£1.17 billion). The biggest part of Russia's military satellite constellation involves 51 communications spacecraft, with 16 Earth-observation satellites.

At the most recent meeting of the United Nations Committee on the Peaceful Uses of Outer Space, states worried that “preventing conflicts in outer space and preserving outer space for peaceful purposes” is more necessary than ever. Since 1967, human activity in space has been guided by the universally accepted principles embedded in the Outer Space Treaty. This has ensured no military conflict in space thus far, and required the exploration and use of space “for the benefit and in the interests of all countries.”

The ESA's director general, Jan Wörner, tells **All About Space** he is against the military uses of space: “It should be used exclusively for peaceful purposes, although some people have interpreted ‘peaceful’ as being for defence. We have enough problems with military conflict on Earth. France is going in the same direction as the US.”

The ISS is an excellent example of what the world should be doing in space, rather than militarising it and increasing inter-nation suspicion. “We should use space for all humankind. Coming from Germany, I've had enough of walls and wars. Military space will lead to a proliferation of space debris, which is becoming a huge problem. Space is a bridge over troubled water, and should remain as such,” concludes Wörner.

Ian Parker
Space industry writer
Ian has written about space since 1985 and is the former editor and publisher of *Space* magazine. He has spoken at many space industry conferences.

SPACE WARFARE IN THE NEWS

IRAN LAUNCHES MILITARY SATELLITE

Last April Iran launched an imaging satellite called Noor from its central desert using a Qased rocket. This comes after a string of launch failures and is worrying to other countries because Iran could use the technology to develop an ICBM.

RUSSIA LAUNCHES ANTI-SATELLITE WEAPON

Last December, in its third anti-satellite test of the year, Russia launched a direct-ascent anti-satellite (DA-ASAT) missile. These can destroy small satellites in low-Earth orbit.

CHINA LAUNCHES FINAL BEIDOU

On 23 June 2020, China launched its final BeiDou satellite to complete global coverage of its civilian and military precision navigation and timing system. There are currently 35 BeiDou satellites in orbit.

©NASA/JPL-Caltech

WEIRD GAS GIANT HOLDS SOLAR SYSTEM'S SECRETS

A gigantic alien world's long orbit may tell us more about the outer planets in our solar neighbourhood

Scientists have managed to measure both the size and orbit of a gas giant exoplanet nearly 1,300 light years away from Earth. Dubbed GOT 'EM-1b, which stands for Giant Outer Transiting Exoplanet Mass, the planet is roughly five times the mass of Jupiter.

Usually scientists struggle to measure the size of giant gas planets, like Jupiter and Saturn, because they're far away from the stars they orbit. Yet this planet showed up in what researchers call our 'solar neighbourhood' in 2010, when NASA's Kepler space telescope first discovered the object. Astronomers then noticed periodic decreases in the brightness of a nearby star, called Kepler-1514, which clued the researchers in to the possibility of planets.

The research team at the University of California, Riverside, discovered that the planet, officially Kepler-1514 b after its parent star, has an unusually long orbit of 218 days. "Taking 218 days to orbit a star is an order of magnitude longer than most giant exoplanets we've measured," said Paul Dalba, the astronomer who led the research. Of the thousands of planets Kepler has discovered, only a few dozen have had orbits of 200 days or longer.

It's possible that learning more about GOT 'EM-1b and giant planets like it could tell us more about the Solar System. "This planet is like a stepping stone between the giant planets of our own Solar System, which are very far from our Sun, and other gas giants that are much closer to their stars," said Dalba.

The discovery of a giant planet that hasn't moved closer to its star over time will serve as an analogue to the gas giants in our Solar System and tell us about how normal our Solar System is in its stability and development. Astronomers believe that Jupiter might be protecting Earth from other objects in space that might otherwise impact our planet, giving our 'blue marble' relative stability.

> "USUALLY SCIENTISTS STRUGGLE TO MEASURE THE SIZE OF GIANT GAS PLANETS BECAUSE THEY'RE FAR AWAY FROM THE STARS THEY ORBIT"

STARSHIP MISSION CONSTRUCTION KIT

SpaceX is building Starship specifically to reach Mars, but it could transform space travel as the first mass-produced spacecraft

Over the last 18 years, SpaceX has cut the cost of space access dramatically, forcing competitors to reluctantly follow its lead, but it is with the new Starship and Super Heavy that SpaceX could revolutionise space travel.

Elon Musk's overarching goal with SpaceX is to establish a self-sustaining city on Mars and make life multi-planetary. The biggest obstacle to this is space transport; the Falcon 9 was designed from a clean sheet to prove the technology and build SpaceX as a business that could reach for Mars. SpaceX focused on fast, simplified manufacturing and operations to bring costs down, but probably its biggest innovation so far was realising reusability could be achieved with conventional two-stage rockets.

As the design has evolved, Falcon 9 has become more capable, but a bigger vehicle was always going to be required to reach the Red Planet. After running through a number of concepts and names - Falcon XX, Mars Colonial Transporter, Big Falcon Rocket (BFR), Interplanetary Transport System - that vehicle has become the Starship reusable spacecraft and Super Heavy reusable first stage.

Space enthusiasts have been following the slow build-up at Boca Chica, but Starship flights have broken out into the broader world, capturing attention in a way reminiscent of the early Space Race. While not as spectacular as the launches themselves, SpaceX's next great innovation shows in the rate new test vehicles arrive, with Starships SN1 to SN9 tested over roughly 12 months.

Driven by the huge number of spacecraft needed for Musk's Mars ambitions, and building on Tesla's mass-production experience, SpaceX

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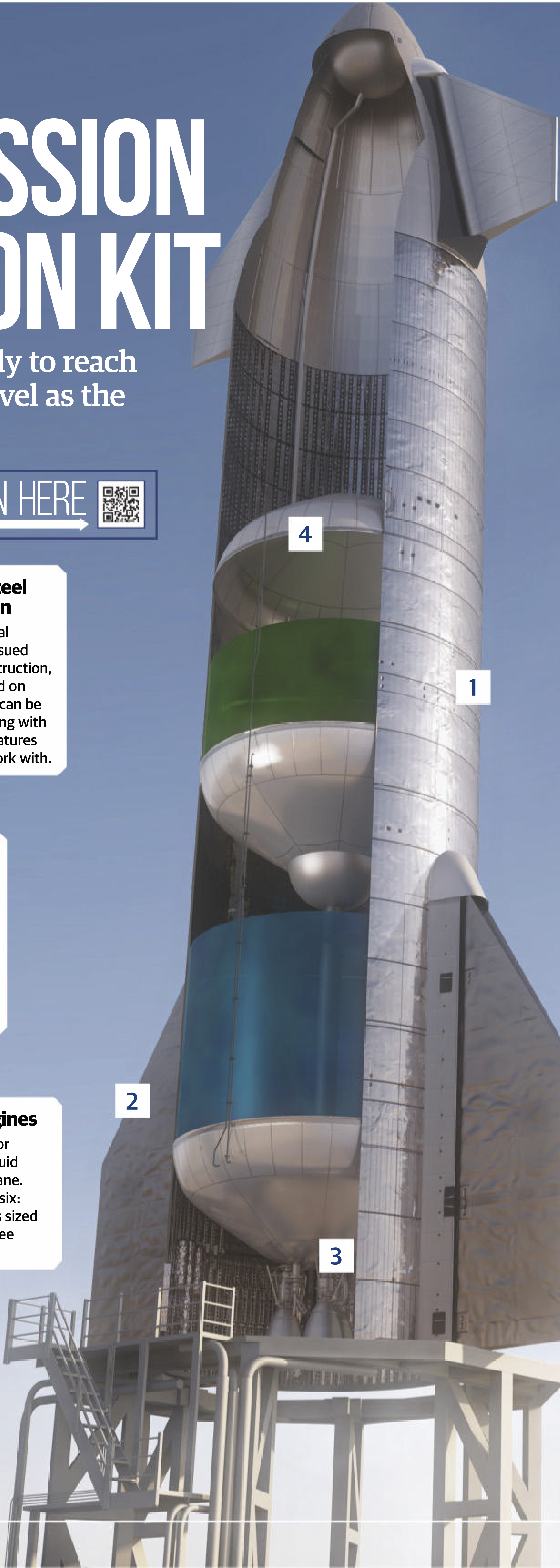


1 Stainless-steel construction
Though the original BFR concepts pursued carbon-fibre construction, SpaceX has settled on stainless steel – it can be lighter when dealing with cryogenic temperatures and is easier to work with.

4 Payload volume
Starship will be able to accommodate huge payloads, and can be built for cargo or interplanetary passengers.

3 Raptor engines
SpaceX's Raptor engines run on liquid oxygen and methane. Starship will have six: three with nozzles sized for launch and three sized for space.

2 Flaps
Key to Starship's mission profile are its flaps. They may look like wings or fins, but they are actually flaps to control the vehicle's sideways reentry.

has built a production line for Starships even as it builds prototypes. Musk is targeting only $5 million (£3.6 million) per Starship. Airliners from Airbus and Boeing are in the region of $100 million (£73 million), though they are admittedly more complex. Even if SpaceX is ten-times above that target, the availability of an off-the-shelf spaceship for less than the cost of an A320 or 737 would transform spaceflight beyond SpaceX.

The first sign of this is SpaceX's involvement in NASA's lunar lander program; to achieve NASA's current lunar return plans, the agency needs a cost-effective lunar lander capable of delivering a significant payload to the surface. Two other teams, including Blue Origin, are building relatively conventional landers, but SpaceX is producing a revision of Starship, a now-proven vertical-landing cargo rocket. Shorn of its atmospheric flaps for the airless Moon and with the addition of mid-mounted landing engines to avoid blasting its landing point with its main engines, SpaceX expects to be able to provide a lunar Starship in time for 2024.

Another potential application for Starship is as the basis for space stations; the International Space Station (ISS) has been progressively assembled by 40 launches over 22 years, with a total cost of around $150 billion (£109 billion), and has a pressurised volume of 1,000 cubic metres (35,314 cubic feet). Figures have varied, but Starship is expected to have somewhere between 850 and 1,000 cubic metres (30,000 and 35,314 cubic feet) of pressurised volume. Even though it's designed to be a spaceship, at anywhere less than $100 million (£73 million) plus launch costs, the mass production of Starship would make it cost effective to buy one to be a space station.

In a similar manner, SpaceX intends to launch dedicated tanker Starships to refuel the Martian Starships in Earth orbit ready for their trip. Of great interest to the broader space industry is the establishment of orbital fuel depots, which could enable full-time multi-mission spacecraft to be refuelled. The Starship tankers will be ready-to-go fuel depots kitted out for dispensing liquid oxygen and methane in zero gravity, and likely even cheaper than the passenger carriers. Again their mass production would make them cost effective to use to build a permanent depot, supplied by more Starship tankers.

Though built in the service of Musk's Mars plans, Starship has the potential to do more. By building the 'machine to build the machine' making Starship cheap and standardised, Starship could be a combination of the DC-3, the first modern airliner, and the shipping container - those ubiquitous metal boxes that move most global freight, and then get used for offices, sheds, houses and all manner of things because they are cheap and available.

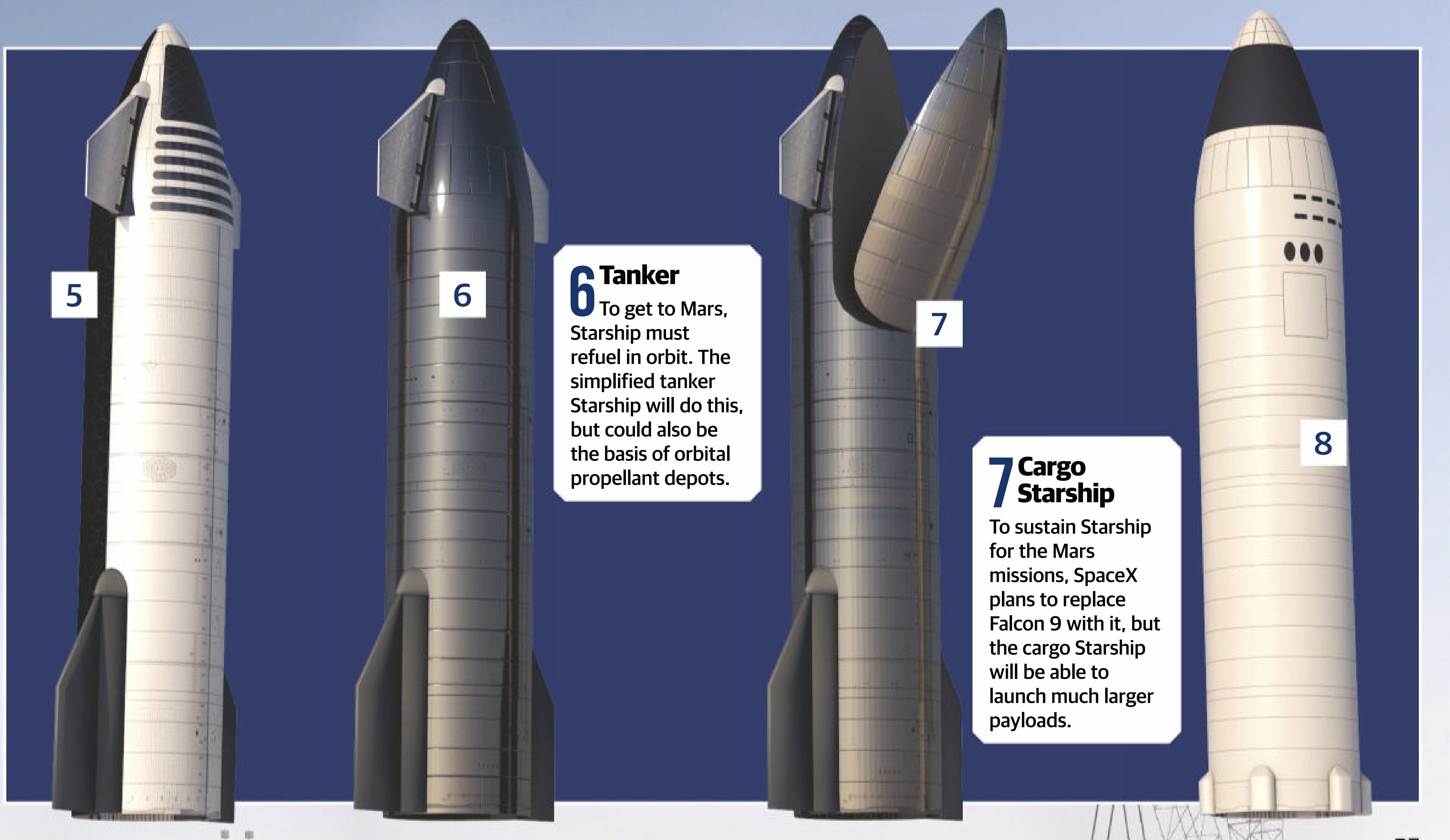
> "AN OFF-THE-SHELF SPACESHIP FOR LESS THAN THE COST OF AN A320 OR 737 WOULD TRANSFORM SPACEFLIGHT"

5 Crew ship

Starship is designed around getting 100 people to Mars, but if it can be made as cheaply as Musk hopes it will dominate crew transport.

8 Lunar Starship

Being designed as part of NASA's return to the Moon plans, the lunar Starship would shuttle between lunar orbit and the surface, supporting future bases.



6 Tanker

To get to Mars, Starship must refuel in orbit. The simplified tanker Starship will do this, but could also be the basis of orbital propellant depots.

7 Cargo Starship

To sustain Starship for the Mars missions, SpaceX plans to replace Falcon 9 with it, but the cargo Starship will be able to launch much larger payloads.

© Adrian Mann

INTERVIEW

BIO

Dr Philip Goff

Goff is a philosopher and consciousness researcher at Durham University. His first popular non-fiction book, *Galileo's Error*, argues that consciousness is present at some level in all things and that integrating it into our scientific understanding of the universe is crucial to comprehending the fundamental nature of reality.

DR PHILIP GOFF

“WE MIGHT HAVE TO RETHINK WHAT SCIENCE IS”

In his book *Galileo’s Error*, philosopher Philip Goff argues consciousness is everywhere. **All About Space** meets with the author to find out more

Interviewed by Connor Hansford

Is there more to life than meets the eye?
I think you should always be open to that possibility because science and philosophy take strange twists and turns, so we shouldn’t assume the paradigm we are currently working with is correct. We don’t know about our feelings and experiences through observation; we know about them through being immediately aware of them. People agree there is a deep problem of consciousness, but the challenge of consciousness is radically different from any other explanatory enterprise because the thing we are trying to explain is not observable. It doesn’t mean we can’t do science with it, but it might mean we have to rethink what science is.

Many people reading this will be scientists for whom consciousness is still a taboo subject. What would you say to them?
The high point of consciousness-phobia was probably the middle of the 20th century where people struggled to get jobs if they wanted to work on consciousness. A lot has changed since then, and it is broadly taken to be something we do need to address scientifically.

In a way those people who were suspicious of it in the 20th century had good reason to be, because it’s not publicly observable in the way other scientific data is. There’s a similar issue in quantum mechanics. It’s the best predicted theory we have and so much of our technology is based on it, but the problem is no one knows what that theory is telling us about reality.

What is the difference between being alive and being conscious?
There is an emergence of people who are not panpsychists who don’t think inanimate matter is conscious, but they do think everything living is conscious, and they defend that on empirical grounds. As to which things are conscious, that’s a question for neuroscientists rather than philosophers to settle and it’s a very difficult question because it’s not publicly observable. We can scan people’s brains to try and work out how experience at the macroscopic human level corresponds with brain activity, and then we can try and generalise this. An implication of the IIT (integrated information theory) is that the cells of the plant are conscious, but the plant itself isn’t, so we should think of a plant as a community rather than a conscious entity in its own right. If you’re a panpsychist it opens up the possibility of plants and animals being conscious, but a plant’s dead when you eat it as well. Obviously you’ve got to eat something. Just try to be as respectful as you can to living things, even if you end up killing them.

Is panpsychism just a way of articulating what native cultures from around the world have known for millennia?
If you think a tree is just a mechanism, then its value is just in terms of what it does for us. If a tree is a conscious organism then chopping it down is an act of immediate moral significance. I would say that the root of panpsychism and the kind of panpsychism that is currently taking off in Western analytic philosophy of mind is very different to other traditions. The starting point of Arthur

© Alamy

Left: Computers have not yet passed the Turing Test, or 'Imitation Game'

Below: We're close to gaining a full understanding of maggot brains

> OUR CURRENT SCIENTIFIC PARADIGM IS TELLING US THERE IS SOMETHING RADICALLY WRONG WITH PHYSICS

© Getty

Source: Wikipedia Commons © Public Domain

Left: Galileo Galilei, whose mathematical understanding of the cosmos rests on the removal of consciousness

Eddington and Bertrand Russell was the realisation that physical science doesn't tell us what matter is, and the theoretical possibility of incorporating consciousness as the intrinsic nature of matter. Consciousness is the thing we understand. Maybe the intrinsic nature of matter constitutes conscious experience. Maybe there are connections, but it's a very different intellectual trajectory that's not necessarily wrapped up with anything spiritual or mystical. A lot of people defending this view are complete atheists, so there are important differences as well as potential connections.

The double-slit experiment proves atoms behave differently under observation. Why is this?

That's a deep mystery. I actually don't think panpsychism can help with this. Among philosophers of physics, the many-worlds equation is the most popular because it gets rid of collapse, so you get rid of the problem of how observation is making a difference.

Before we observe the system, we get interference patterns, and then this disappears and we just get particle behaviour, so whether you're looking or not makes a difference between waves and particles. If you're a panpsychist, you can't say it's consciousness that makes a difference because consciousness is everywhere, so we never have the distinction between before and after collapse or wave behaviour and particle behaviour.

Where it might help is a mind-body dualism where consciousness is outside the workings of the physical brain. The puzzle for the dualist is how the mind and brain interact. If you have this interpretation of quantum mechanics, you might want to say it's non-physical consciousness.

Is it important to understand consciousness?

We're about 70 per cent of the way through having a complete understanding of a maggot brain - which is smaller than the dot on an i - so we're a very long way from understanding the 86 billion neurons in the human brain. We have a good grip on the basic chemistry, but what we're clueless on is how those large-scale functions are realised at the cellular level. If it was true that there is a non-physical consciousness impacting on the brain every second, that would show up in neuroscience. The more I talk to neuroscientists, the more I think we don't know enough about the brain to assess whether there is non-physical influence on the brain. I'm not saying there's a reason to believe dualism, but I'm not sure we know enough about the brain to rule it out.

Do you believe that dark matter exists, and could it hold the key to understanding consciousness?
I'm not qualified enough to make such a judgement, although I do sometimes wonder whether our current scientific paradigm is telling us there is something radically wrong with physics. I don't think we need dark matter to get mystery. Physics tells us how matter behaves, but we don't know the substance of the stuff in and of itself, so the whole thing's a mystery. It's the conscious mind you understand because we're in direct contact with it. Eddington thought we needed to build our conception of matter around our understanding of consciousness, which completely turns the mind-body problem on its head.

The Space Shuttle program was retired in 2011. Is it possible to amass enough empirical data about the Space Shuttle to have a qualitative experience of it?
Consciousness is subjective, so you can only understand something if you adopt its perspective. It would depend on how similar our own experiences are. Maybe you could know what it's like to have experience of red if you've experienced a similar colour. I don't think any amount of quantitative data can add up to that. If you've never been on the Space Shuttle but you've had experiences that are in some way similar, maybe you can start to have a grip on it.

So can machines think?
A neglected issue in AI is the relationship between thought and consciousness. Some philosophers think they're different things, whereas a growing minority think thought is a highly evolved form of consciousness. Imagine we one day have a silicon duplicate of a human being. Let's say silicon things are not conscious, but they're set up to be behaviourally just like a human being. Suppose you're talking to it and it's opining about how best to deal with the pandemic or the global economy, but it's not conscious. Would we say it really has opinions? If thought is just about information processing, yes, but I am inclined to say it doesn't really understand anything. If you remove a part of the brain you lose a lot of information, whereas a computer is not like that. It can store a lot of information; the way it does so is not as dependent on a complex web of connections. If IIT is right, computers along the model we currently have will never be conscious. In many ways we're not at first base when it comes to thinking through these issues properly, but that's also why it's very exciting!

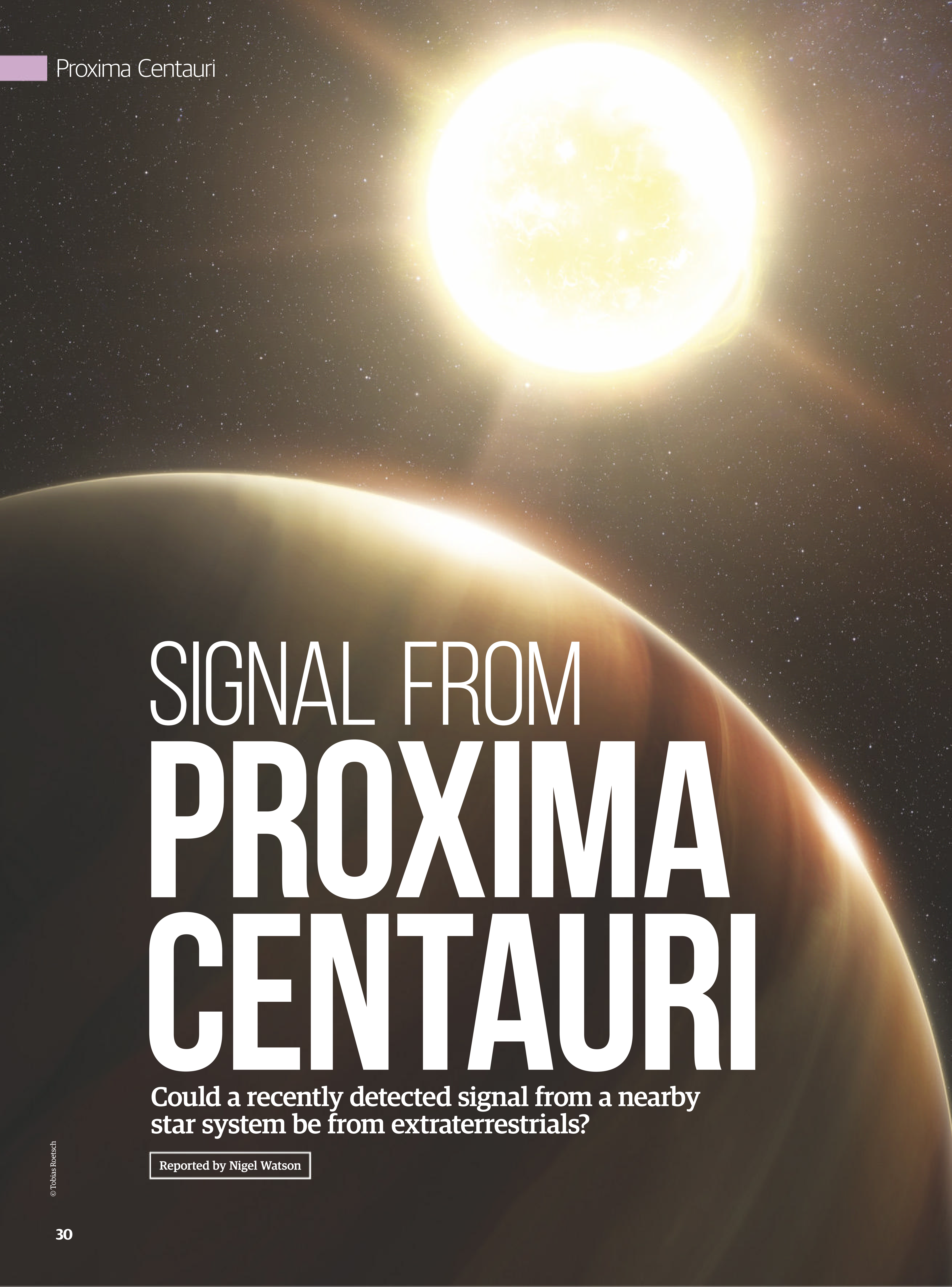
© NASA

Right: Our experiences can help us understand how it feels to fly to space

Below: Physics is mysterious enough without dark matter, says Goff

AR SCAN HERE

© NASA



SIGNAL FROM PROXIMA CENTAURI

Could a recently detected signal from a nearby star system be from extraterrestrials?

Reported by Nigel Watson

© Tobias Roetsch

Unusual signals from outer space are exciting as they indicate something new and unexpected, and might even turn out to be much anticipated communication from an extraterrestrial civilisation. There was even more speculation surrounding the recent detection of signals from the direction of Proxima Centauri because it is our closest stellar neighbour. They were spotted by student Shane Smith, working under the Breakthrough Listen program, as he went through the slow and laborious process of searching through data that was originally collected to detect stellar-flare activity.

The data was collected by the Parkes radio telescope in New South Wales, Australia, during a 26-hour observation period starting on 29 April 2019. Smith sifted through the data for several months in 2020 to see if it showed any sign of a 'technosignature' that would indicate Search for Extraterrestrial Intelligence (SETI) activity, and it wasn't until October 2020 that he finally found something very unusual. It was a narrowband emission at 982.002 megahertz.

The signals had passed the many automated filter systems that sort through millions of signals to rule out terrestrial interference, errors and static. A technique called 'nodding' was also used to highlight spurious signals. This involves pointing the telescope at one target in the sky for a fixed period, then moving to a second target for the same amount of time. This is to determine if any unusual signals are coming from a specific place rather than being caused by something more general and mundane. In this case it seems the signal did come from the specific direction of Proxima Centauri and not by anything in the area of the telescope like a nearby microwave oven or anything else terrestrial.

As a consequence, the signal has undergone further analysis, and unlike hundreds of other signals that at first looked unusual, it has been intriguing enough to be labelled 'Breakthrough Listen Candidate 1' (BLC1). Even so, we must keep in mind that SETI research is littered with many false alarms, the most famous being the so-called Wow! signal received in 1977 by the Big Ear radio

Right: Distant alien civilisations could be sending messages to us, but do we have the technology to receive and understand them?

© Getty

COULD IT BE ALIENS?

There are many challenges to defining whether a signal from outer space is an indication of alien contact or something less exotic

REASONS FOR

1 The signal originates from the direction of an exoplanet orbiting in the habitable zone of Proxima Centauri.

2 Aliens would likely target signals to planets like Earth that are also in the habitable zone of their star.

3 The closeness of Earth would also encourage any extraterrestrials in the Proxima Centauri system to specifically target us with a signal.

4 Whatever the sceptics' objections are, Garrett notes the signal has "some of the properties you are looking for in a good SETI candidate".

REASONS AGAINST

1 Despite filtering systems, it could be due to an equipment malfunction or could have rare terrestrial or natural origins.

2 There are a multitude of stars in the telescope's field of view of 12 arcseconds, and the signals might not be coming precisely from Proxima Centauri.

3 It would be incredible that the first ET signal would be from our closest star system.

4 It needs to be detected again in the same position by more than one radio telescope before we get too excited. As Wright notes: "We can't study it if it's so ephemeral that we never get a good look at it again!"

Right: The 3.6-metre (11.8-foot) telescope at La Silla Observatory, Chile, under the Milky Way. The two bright stars directly above it are Alpha Centauri A and B

© ESO

telescope at Ohio State University. Radio astronomer Jerry Ehman was so impressed by the 72-second-long signal that he wrote 'Wow!' next to the code 6EQUJ5 on the computer printout. It was a strong and rare signal near to the 1,420 MHz frequency hydrogen line, which by international agreement is unauthorised for radio transmissions. It seemed to be coming from beyond the Moon, but not from any planetary object or known star or galaxy. Satellites, space junk or just plain equipment malfunction were also ruled out as sources.

Frustratingly, the Wow! signal has never been detected again, despite the fact that hundreds of attempts have been made over a wide range of frequencies. It may have been a very short-lived and half-hearted attempt by ET to send a message, or it was possibly a Sun-orbiting spy satellite using an illegal frequency. Another explanation came in 2017 when Antonio Paris from the Center for Planetary Science at St. Petersburg College in Florida, after studying the trajectory of comet 266P/Christensen, suggested that it had caused the Wow! signal. The main objection to this explanation is why the signal was not detected again by Ehman and his team. The Wow! signal remains a fascinating piece of SETI history and shows how difficult it is to pin down the origin of unusual signals.

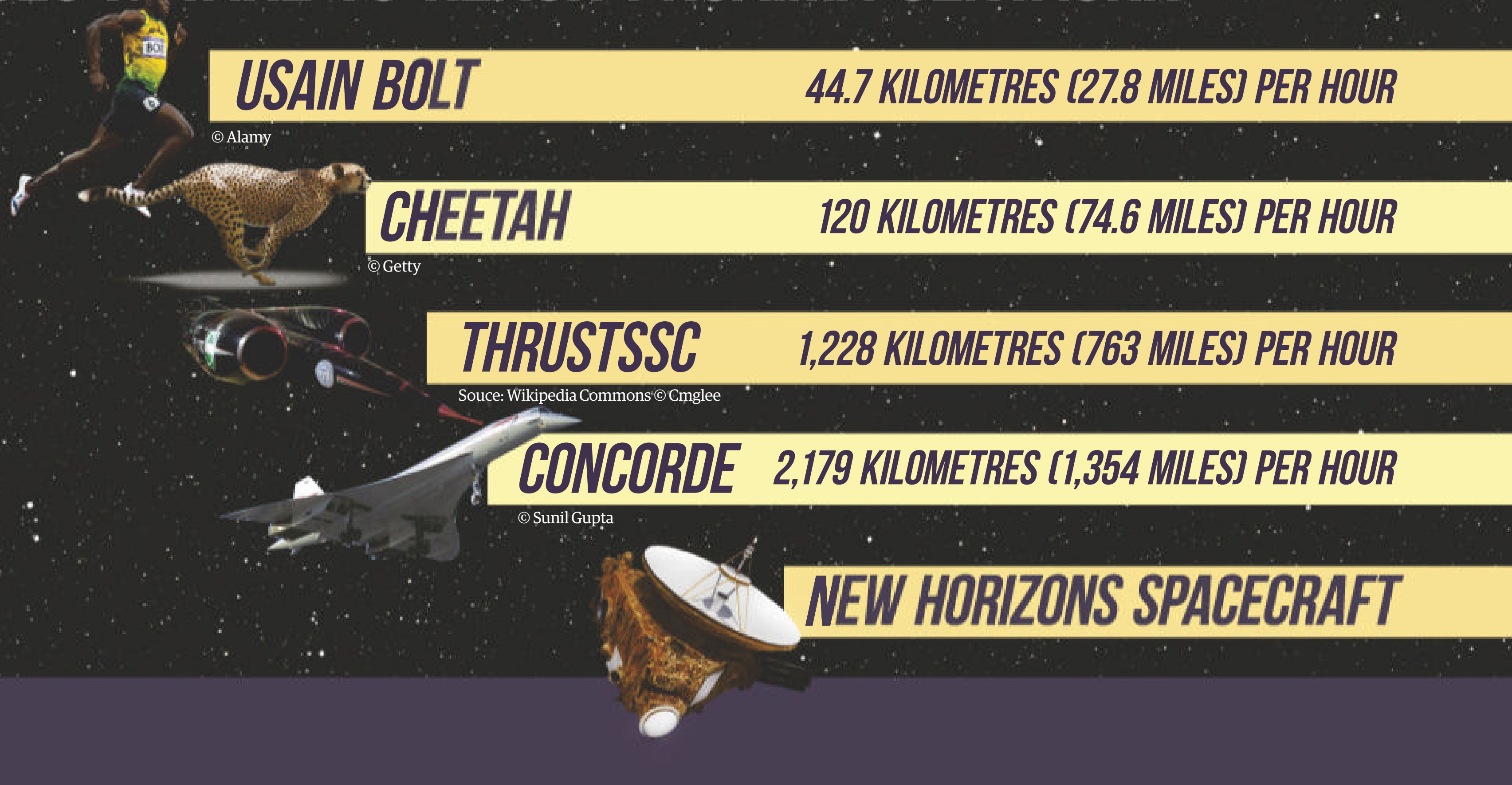
Unlike the Wow! signal, BLC1 is at least believed to be coming from the direction of Proxima Centauri, but it is nearly as elusive. As Professor Michael Garrett of the University of Manchester observes: "I think it is a much more interesting candidate than the Wow! signal - very likely it was either human-made interference or natural radio emission from a cosmic object. BLC1 is interesting because it was narrow band, was detectable for several hours and drifted in frequency."

As Garrett says, it would be very surprising for us to receive an ET signal from such a close stellar system, especially when we consider that there are at least 300 million exoplanets in our galaxy that have remained steadfastly silent. In addition, it would be an equally big coincidence that its inhabitants are using technology similar to our own, implying that they are at a similar stage of evolution and have similar thinking and technological abilities as us. It is a general burden to SETI programs that we can only look for ET in terms of our own expectations and scientific knowledge. Any signals we do detect would be from beings that are advanced enough to create them, but not too advanced that they are far beyond our own technology to detect or understand.

Jason Wright, professor of astronomy and astrophysics at Penn State University, argues that if there is a galactic community, or even an advanced civilisation on a single planet, they would likely set up a communication network in a similar manner to our mobile networks. Proxima Centauri would be a good location for part of this network, and is not necessarily transmitting specifically to us.

HOW LONG DOES IT TAKE TO REACH PROXIMA CENTAURI?

Although it's the nearest star to our Solar System, the time it would take to get there using our current technology is still staggering. At a distance of 4.24 light years – 1.3 parsecs or 268,770 astronomical units – that sounds fairly close, but when we consider that this equates to 40,208,000,000,000 kilometres (24,984,092,897,478 miles) away then things are put into perspective. At best it would take us several thousand years to get there.


USAIN BOLT
44.7 KILOMETRES (27.8 MILES) PER HOUR
CHEETAH
120 KILOMETRES (74.6 MILES) PER HOUR
THRUSTSSC
1,228 KILOMETRES (763 MILES) PER HOUR
CONCORDE
2,179 KILOMETRES (1,354 MILES) PER HOUR
NEW HORIZONS SPACECRAFT

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Alternatively, if they did want our attention then Proxima would be a good location, as they would guess that if we have the technology to conduct SETI research we would look in this direction.

As for Proxima Centauri itself, it was discovered in 1915 and is an M-type star visible only in our Southern Hemisphere, residing in the Centaurus constellation. At a distance of 0.2 light years it orbits the Alpha Centauri A and B binary-star system, which to the naked eye looks like one star.

Proxima Centauri is 500-times dimmer than our own Sun, so it's not visible to the naked eye. Being a red dwarf, it has a mass an eighth of our Sun's and has a temperature of 2,826 degrees Celsius (5,120 degrees Fahrenheit), which is half the Sun's temperature. As it sits at a distance of 4.24 light years from us, travelling at the speed of light the signal would have been transmitted 4.24 years ago, and it would take the same amount of time for us to answer it. That is a long time scale, but nothing compared to the hundreds of years to communicate with other systems in our galaxy.

In August 2016, Guillem Anglada-Escudé and his European Southern Observatory (ESO) team announced the discovery of a planet orbiting the star every 11.2 days within its habitable zone, where liquid water might exist. Named Proxima b, it is estimated that it is 20 per cent larger than Earth, with a mass of 1.27 Earths.

There is a remote possibility that Proxima b could support life on its rocky surface. However, it would have to protect itself and adapt to the fact that its host star blasts out bursts of high-energy ultraviolet and X-rays. This stellar wind is 2,000 times the strength of the solar wind our planet is subjected

WHAT WE KNOW ABOUT THE SIGNAL

A SPECIFIC ORIGIN

The signal originated from the direction of Proxima Centauri. This stellar system is known to have an exoplanet orbiting in the habitable zone of the star.

LONG DURATION

It was a relatively long-lasting signal, making it less likely to be caused by a random equipment malfunction or due to nearby interference.

NARROW BAND

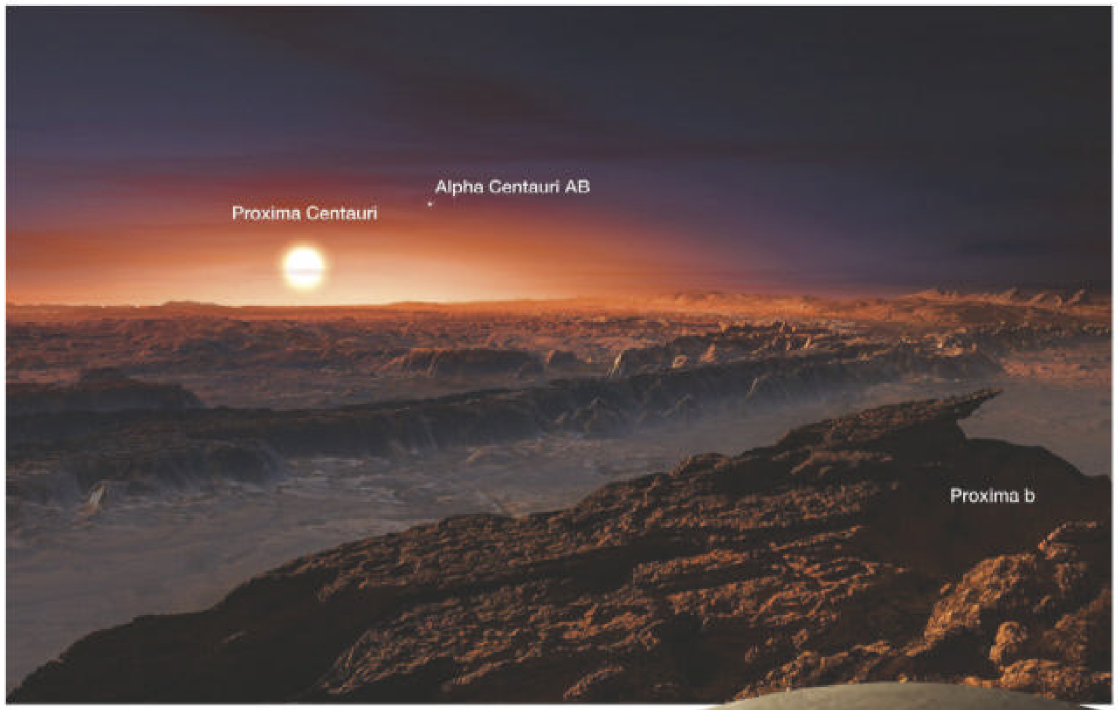
It was a narrow-band signal, another indicator that it was not of terrestrial origin, such as the turning on of a nearby microwave or similar type of appliance.

DRIFTING

The signal drifted in frequency. This shows it was probably originating from a moving source, such as a planet orbiting Proxima Centauri.

IT PASSED SYSTEM FILTERS

Many unusual signals are picked up, but they are usually caused by static or by other mundane factors and are eliminated by automatic filter systems. This signal passed all these filters.



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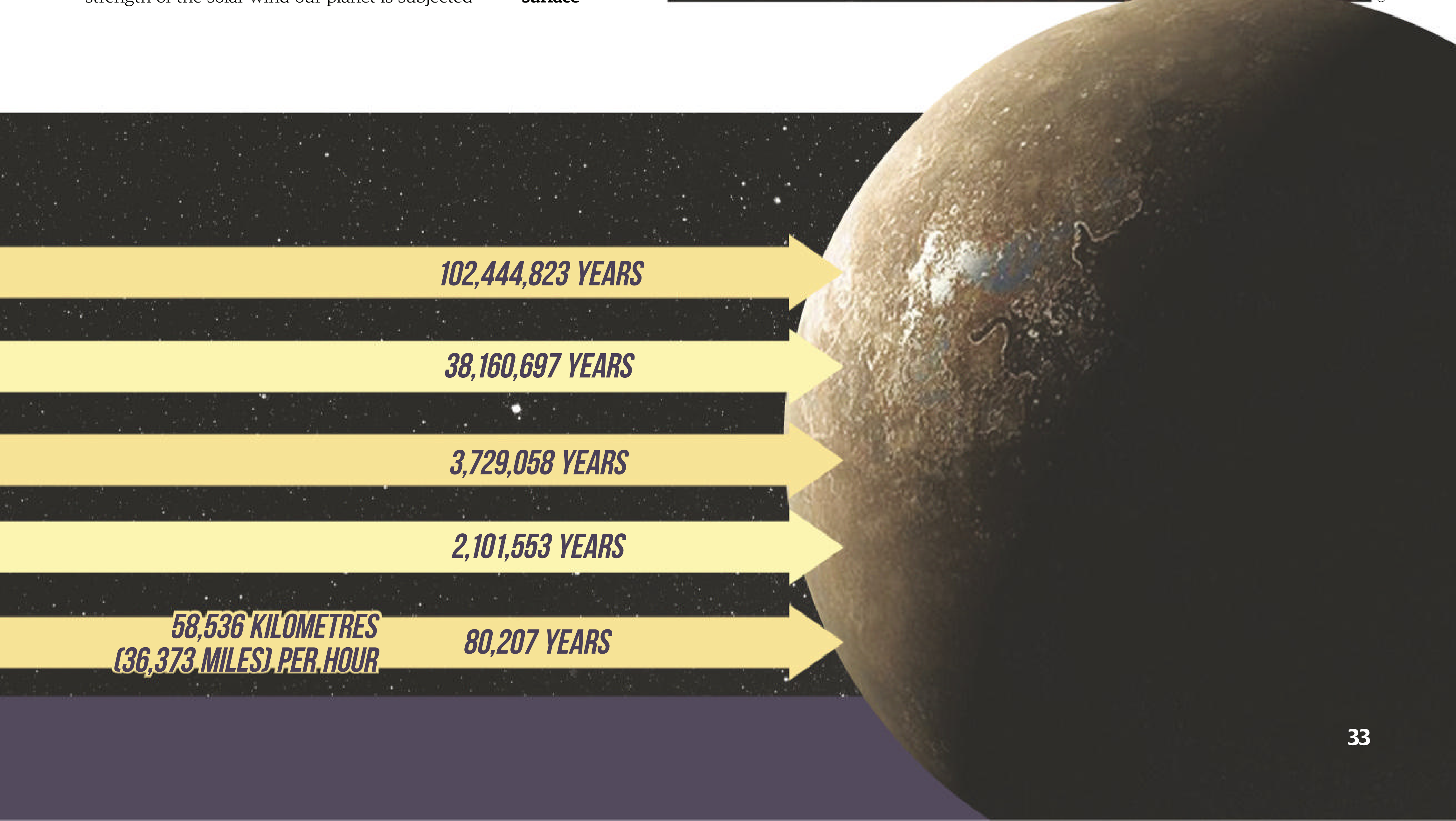
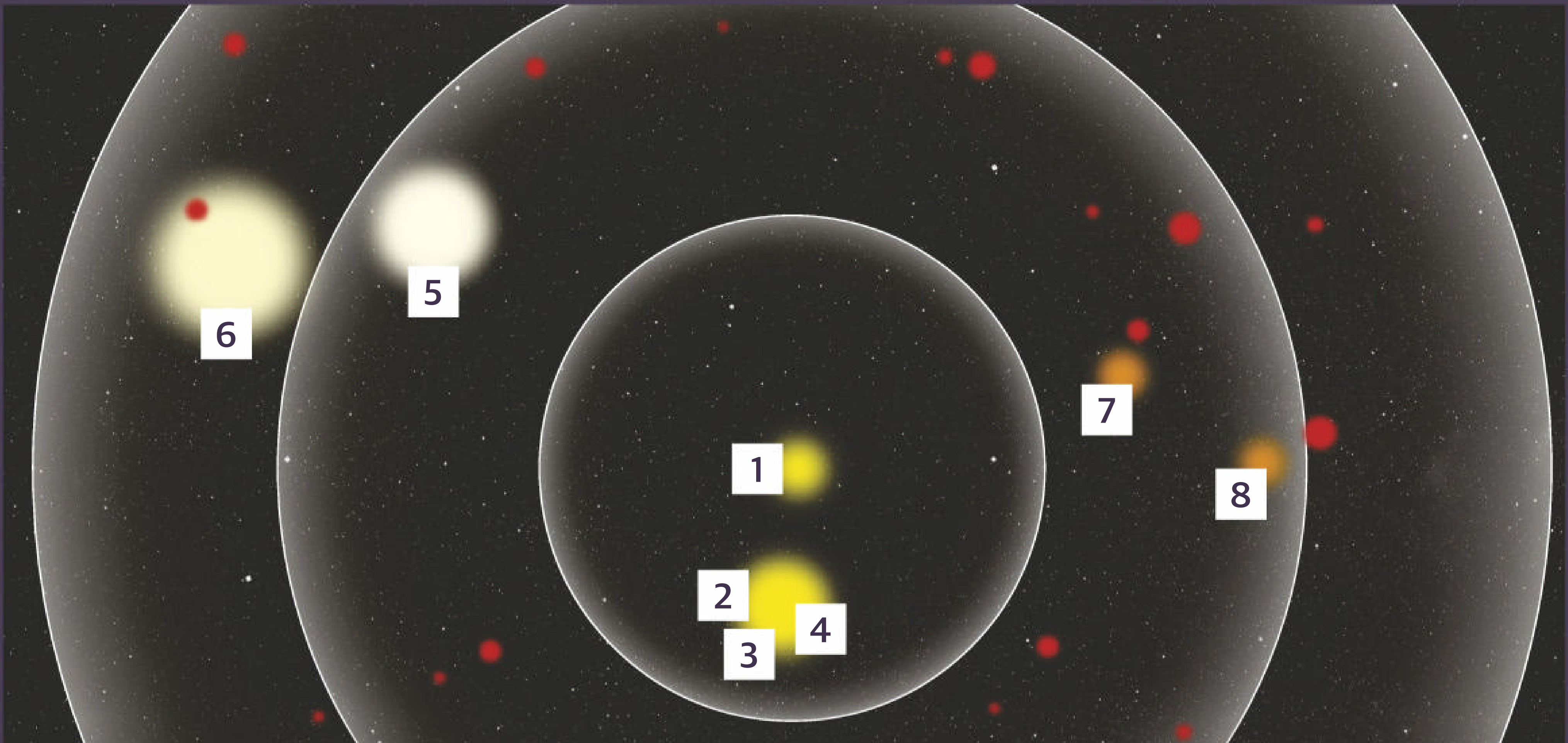
Right: An artist's impression of the rocky surface of Proxima b, where liquid water might exist on the surface





WHERE IS PROXIMA CENTAURI?

1 THE SUN The heat and light from our G-type star has nurtured life on Earth and possibly nurtures primitive life forms elsewhere in the Solar System.

2 ALPHA CENTAURI A 4.36 light years from our Sun, with Alpha Centauri B it forms a binary pair in Centaurus. They are both similar star types to our Sun.

3 ALPHA CENTAURI B This star is slightly smaller than its sibling Alpha Centauri A. The binary system rotates a common centre of gravity every 80 years.

4 PROXIMA CENTAURI At 4.24 light years away, Proxima is the closest star to us. The red dwarf star has two exoplanets. Proxima b is slightly bigger than Earth.

5 SIRIUS Located in Canis Major, Sirius is 8.6 light years away and is twice the mass of our Sun. It has a much smaller white dwarf companion star, Sirius B.

6 PROCYON Another binary system, Procyon A is an F-type star that could turn into a subgiant. Procyon B is a white dwarf. They are both 11.5 light years away, and part of Canis Minor.

7 EPSILON INDI This star in Indus lies 11.8 light years away. This red-orange dwarf star has a methane brown dwarf with its own companion brown dwarf star nearby.

8 61 CYGNI At 11.4 light years away, this is a binary star system in the Cygnus constellation. The two K-type stars are older than the Sun and could host planetary systems.

to, and over billions of years it could well have stripped it of its atmosphere. Nonetheless, it could have retained a thin atmosphere and water on its surface. The world is in synchronous rotation with its star, so one side of it constantly faces its star, much in the manner the Moon always faces us and we never see its dark side. The side of Proxima b facing its star will be very hot, and the opposite face is likely too cold for life, unless it has a thick enough atmosphere to transfer the heat to the frozen side.

A team at NASA's Jet Propulsion Laboratory in California put forward a proposal to send a robot spacecraft to Proxima b in 2069 when we might have the technology to produce a craft to travel at a tenth of the speed of light. It would celebrate the 100th anniversary of the Moon landing and take 44 years to get to its destination. The ongoing Breakthrough Starshot project has the ambitious aim to send a thousand ultralight miniature spacecraft with lightsails attached to them. Once launched from Earth by a mothership, ground-based light beams would push the lightsails of each craft to a speed of 160,934,400 kilometres (100 million miles) per hour to take them to Proxima b in 20 years. Data and images from them would take 4.24 years to be beamed back to Earth.

A second planet, Proxima c, was found in 2019, and is a super-Earth seven times the mass of our planet. It takes just over five years to orbit its star at a distance of 1.49 astronomical units, taking it far beyond the habitable zone. It's very unlikely to support any life forms capable of existing, let alone sending a signal. It's also possible that a ring of debris like that of Saturn's could orbit this planet.

So is the Proxima Centauri system worth looking at in more detail for signals or are there better candidates? "It would certainly be interesting to redetect this signal and study it more closely – for example observing it with a network of radio telescopes well separated across the planet," says Garrett. "That would provide definitive observations of the true nature of the emission. If this is a real SETI signal, it would be very surprising if it were coming from our nearest star – more likely it would be from another star that is also in the field of view of the radio telescope observations. There are millions of galactic stars in the field of view, and the emission could be coming from any one of them – you would need a network of radio telescopes to tell you which one."

Wright anticipates that the Breakthrough Listen team will try to redetect the signal using the Parkes radio telescope, search through the data already collected from Proxima to see if it contains other unusual signals, rule out radio frequency interference (RFI) by checking data collected from other celestial directions by Parkes and research what devices might transmit at the 982 MHz frequency. Pete Worden, the executive director of the Breakthrough Listen project, is realistic enough

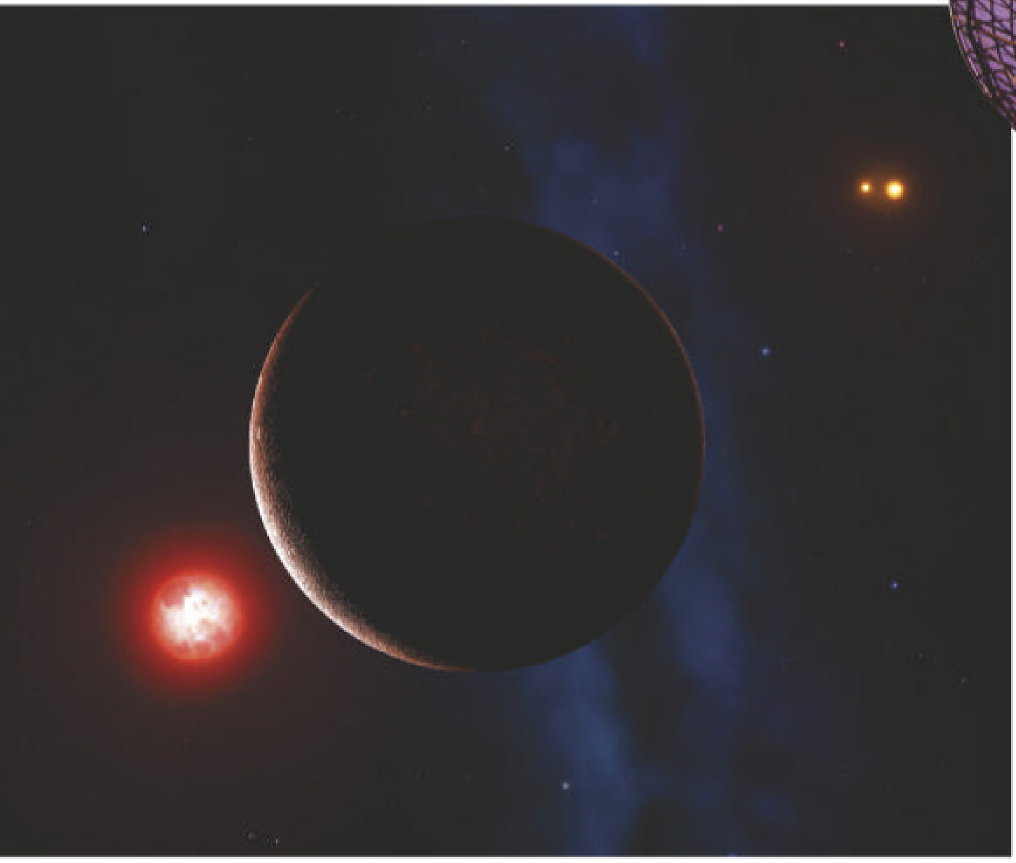
© Getty

to accept that the signal is 99.99 per cent likely to be of human origin.

Some have even suggested that the signal was a hoax or that the data was hacked to make it look like an ET signal. Conspiracy theorists have also pointed out that we only became aware of the signal when it was anonymously leaked to *The Guardian* newspaper. As a Breakthrough Listen advisory board member, Wright notes that although he has no inside information about this signal, they are committed to transparency and scientific rigour, and have extensive post-detection protocols to avoid the situation of second-guessing the data. He is understandably annoyed about this leak before a proper announcement could be made.

Michael Michaud, author of *Contact with Alien Civilizations: Our Hopes and Fears About Encountering Extraterrestrials*, optimistically hopes "that observations of Proxima b by professional astronomers will continue. They are a test case for our ability to detect signals from a technological civilisation. However, the probability of finding such evidence in any one system is low. The best next step is to expand the search to more nearby systems, taking advantage of improving signal-detection technologies." In this sea of speculation, Wright is accepting that we may never know what caused the signal: "If it never repeats and if the team can't find a good RFI explanation then I'm afraid it will be another Wow! signal - an intriguing maybe that we'll just have to wonder about forever."

Nigel Watson
Space science writer
Nigel has written extensively about science and technology, in particular about extraterrestrial contact. He is the author of four books on alien life.



Below: An artist's impression of Proxima b orbiting red dwarf Proxima Centauri, with the Alpha Centauri binary pair shown in the upper left

© Alamy

HOW WAS THE SIGNAL DETECTED?

A survey of stellar flare activity by the Australian Parkes radio telescope revealed the 'alien' signal

1 PARABOLIC DISH The 64-metre (210-foot) dish reflects radio waves from outer space to the focus cabin.

2 FOCUS CABIN Radio waves are converted by the focal point receivers inside the cabin into electrical signals.

3 SUPPORT LEGS Cables run along one of the three support legs, taking these signals to the control tower.

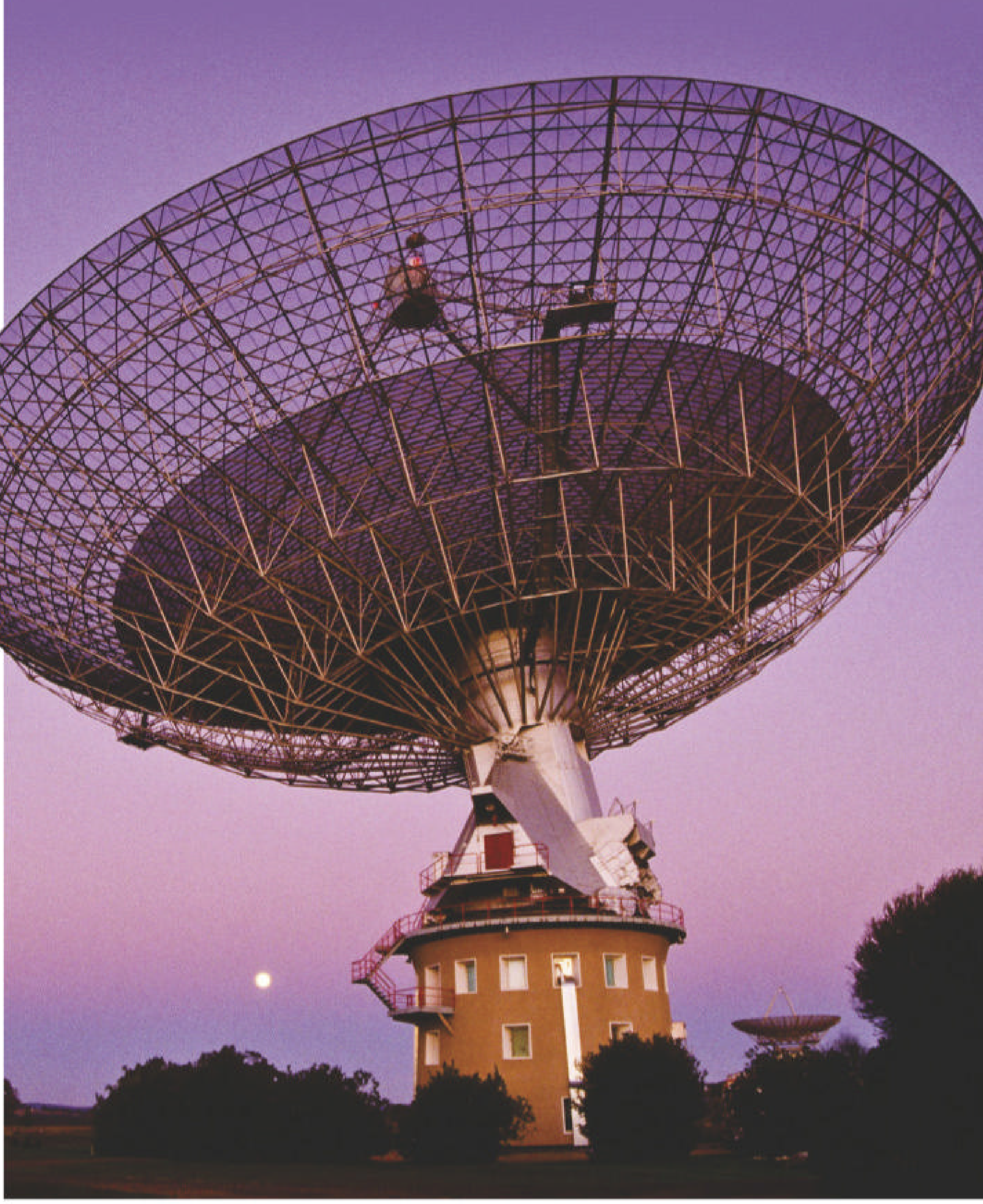
4 CONTROL TOWER Signals are received in the control room, where they are then processed.

5 CONTROL ROOM Computers amplify the weak radio signals, filtering out any radio interference. Recent upgrades have made its equipment 10,000-times more sensitive.

6 TRACK The dish can be rotated 360 degrees on the tracking system and can be pointed with an accuracy of 11 arcseconds.

7 COUNTERWEIGHT This helps keep the 1,000-tonne dish that sits on top of the concrete tower in balance.

8 LOCKING PIN If the wind speed goes above 35 kilometres (22 miles) per hour, the dish is pointed upright and locked into position.



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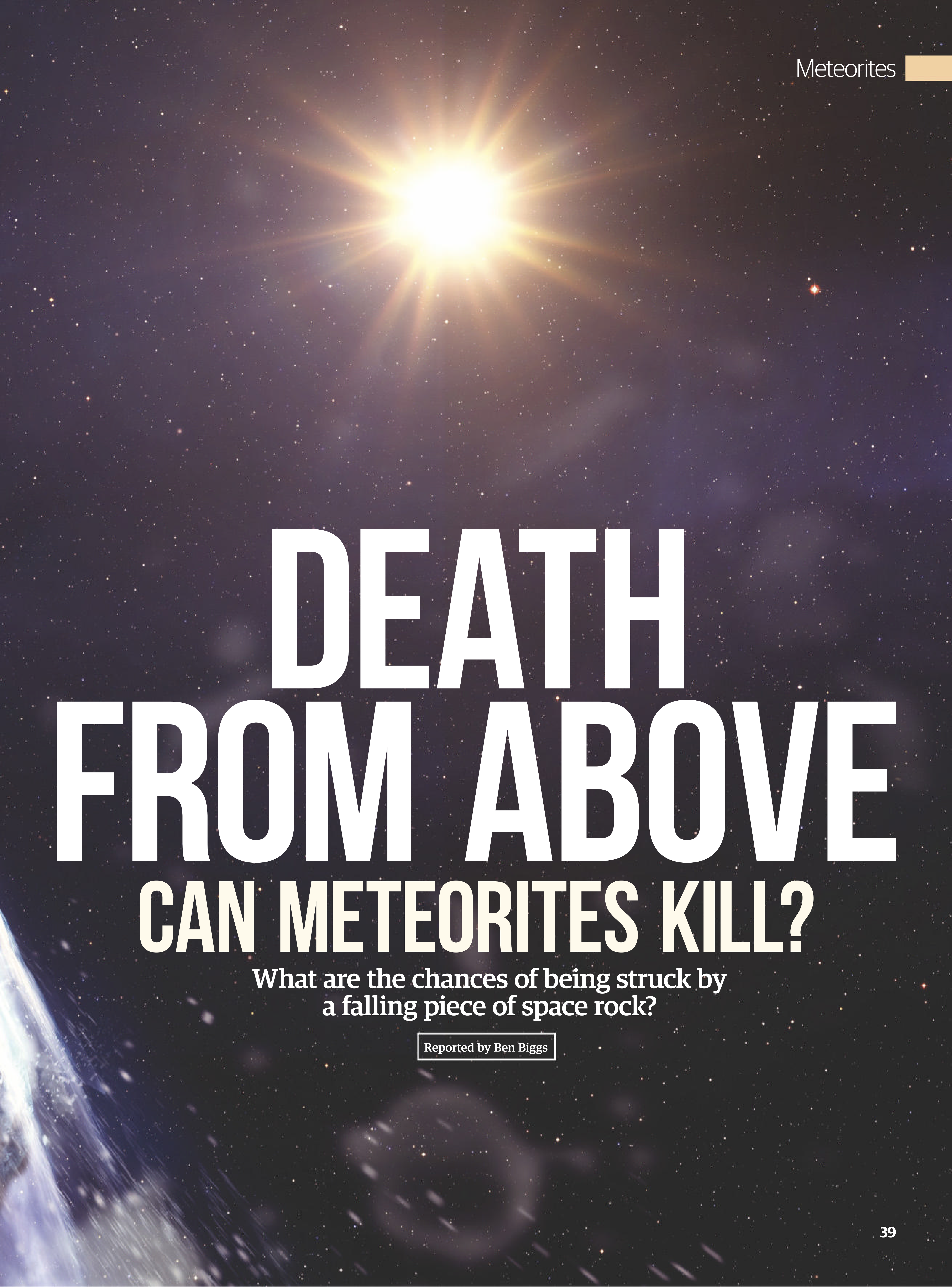

DEATH FROM ABOVE

CAN METEORITES KILL?

What are the chances of being struck by a falling piece of space rock?

Reported by Ben Biggs

On 22 August 1888, a fireball was witnessed over the city of Sulaymaniyah in what is northern Iraq today. It was part of a shower of meteorites that lasted ten minutes, during which time many impacted Earth. To the relief of the citizens below, this blazing celestial missile zipped overhead, missing the city and slamming into a nearby hillside. Unfortunately one man was killed, and another was seriously injured. This event is described in three contemporaneous letters that were found in an archive recently, thought to be the earliest evidence of someone being killed by a meteorite fall. But this isn't the last time that history recorded someone getting hit by a meteorite.

In November 1954, Ann Hodges was having a nap on her sofa in Alabama when a 3.8-kilogram rock punched a hole in the ceiling of her house, ricocheted off her radio and hit her in the side. Ann was taken to hospital and was left with angry bruises, but nothing more serious. In 2009, Gerrit Blank, a 14-year-old German boy, was hit by a meteorite the size of a pea that he said "knocked me flying and then was still going fast enough to bury itself into the road". In February 2016, a death in India was reported to be from a meteorite strike, although NASA later suggested that this unfortunate person likely fell victim to a landmine, or similar explosion. This isn't to suggest that, outside of recorded events, no one has been killed by a meteorite in the last 150 years. But you have to be extraordinarily unlucky to be hit by one of these falling space rocks. Or lucky for that matter, if you survive initial contact and are able to claim the valuable meteorite: a 10.3-gram piece of Ann Hodges' meteorite sold for $7,500 (approximately £5,400) in 2017.

So what were the odds of Blank, Hodges or the two Iraqis being in the exact same place at the exact same time a meteorite found its final resting place? They're pretty slim - bookmakers will give you around ten-times better odds of being struck by lightning on any given day. To give this some

> **"ANN WAS TAKEN TO HOSPITAL AND WAS LEFT WITH ANGRY BRUISES, BUT NOTHING MORE SERIOUS"**

© Getty

Above: Stony-iron pallasites are rare, attractive when properly prepared and quite valuable

NAME THAT SPACE ROCK

What's the difference between an asteroid and a meteor?

Astronomers designate the rocks that float around in the Solar System and enter Earth's atmosphere according to their behaviour and size: most objects larger than one metre (3.2 feet) in diameter that aren't a dwarf planet or planet are asteroids. Meteoroids are smaller than this, but larger than a grain of sand. Micrometeoroids are even smaller than that. Comets are asteroid-like objects made up of ice and dust that have two tails and produce a coma – a small bubble of atmosphere – when they pass close to the Sun. When any of these objects enter Earth's atmosphere and begin to burn up, producing a streak of glowing particles, they're known as a meteor. If any of this meteor survives passage through Earth's atmosphere and hits the ground, it's called a meteorite.

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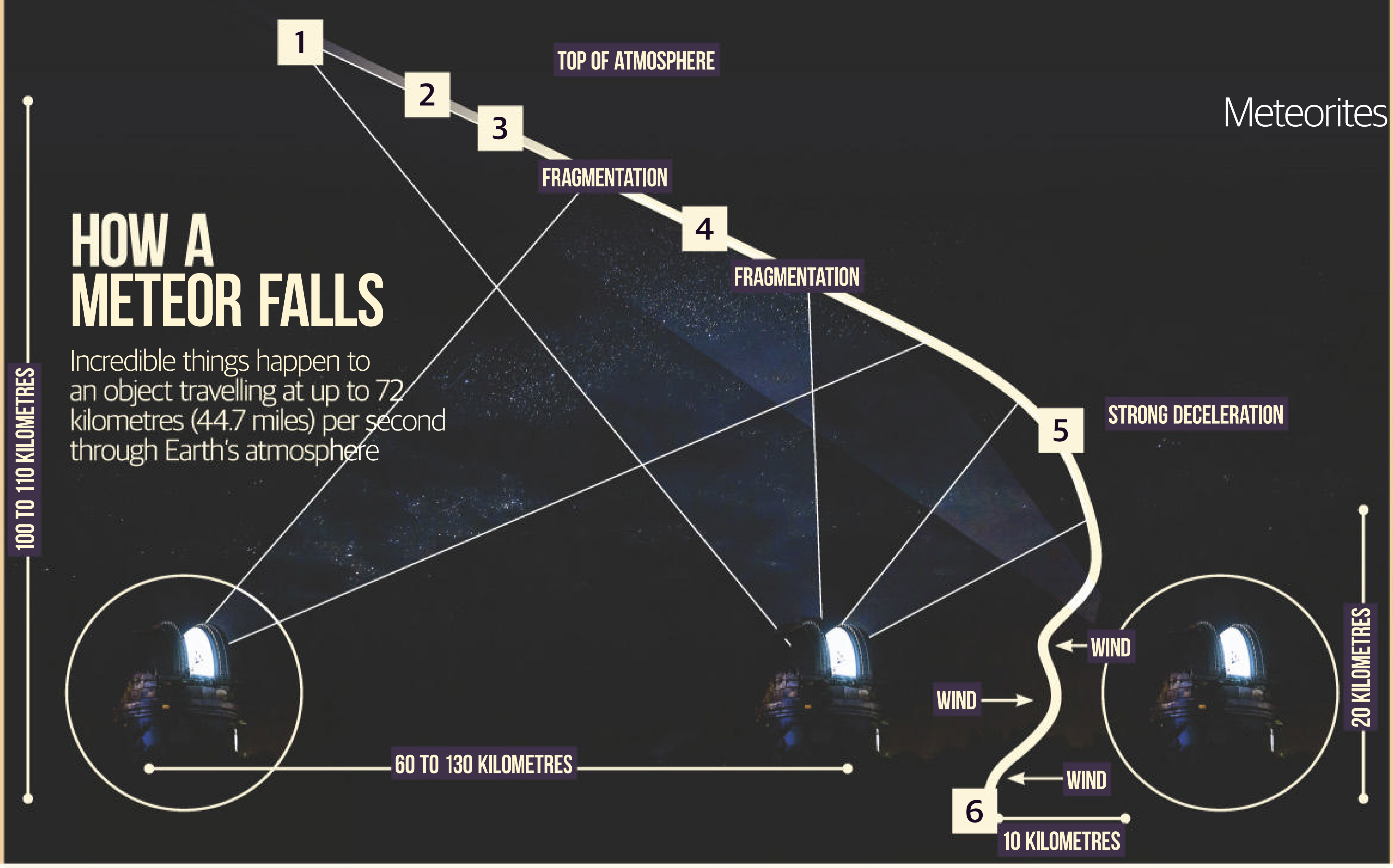


HOW A METEOR FALLS

Incredible things happen to an object travelling at up to 72 kilometres (44.7 miles) per second through Earth's atmosphere

© Alamy

1 Drifting

Objects in space can be drifting for billions of years before their trajectory puts them on a collision course with Earth.

2 Atmospheric entry

As the object zips into the atmosphere at high speed, friction with the air causes the surface to melt and vaporise.

3 Shooting star

Most objects disintegrate, but some will go on to shine with an intense light and leave a short-lived streak of glowing debris.

4 Fireball

Larger objects glow with such energy that they briefly outshine the Sun. They can also burn in different colours and produce shock waves.

5 Dark flight

If anything of the meteor remains after its encounter with Earth's atmosphere, its descent is slowed and it stops glowing.

6 Touchdown

The object – or whatever fragments of it that remain – hits the ground. Depending on its size, the impact can create large craters.

© Getty

Left: Very little was left of the actual meteorite that created the famous Barringer crater in Arizona

Below: The Chelyabinsk superbolide explosion was so powerful it knocked the wall of this factory down

perspective, most meteorites begin as asteroids as old as the Solar System, and have been orbiting the Sun in the asteroid belt, or as part of a bigger asteroid, for billions of years. At some point in their orbit, something happened that changed their trajectory and set them on a collision course with Earth. Perhaps they hit another object, which is highly unlikely given the huge distances between asteroids in the belt, or their orbit was perturbed by the gravity of something larger, like a passing comet or a planet like Jupiter. Then, millions or even billions of years later, their path intersects with Earth as it travels in its orbit. It's very much a case of a butterfly beating its wings on one side of the world causing a hurricane on the other.

Having said that, there's an awful lot of space rock out there, so around 25 million fragments still reach Earth every day. But these rocks have to survive the blistering heat caused by friction as they pass through Earth's atmosphere at speeds of up to around 260,000 kilometres (161,500 miles) an hour. Most of them are the size of a grain of sand, and the vast majority are vaporised by the intense energies associated with atmospheric entry before they can even come close to making landfall. An average of just 17 of these are big and robust enough to survive the transit through the air, often breaking up into smaller fragments before impacting the Earth.

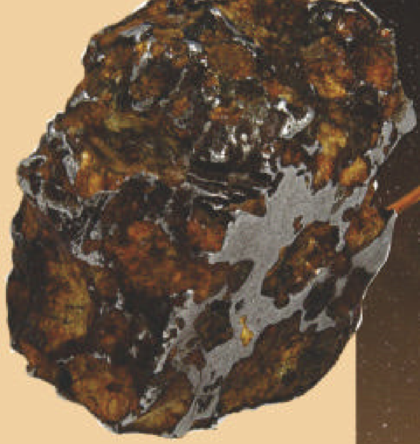
METEORITE TYPES

STONY

They're mostly made of silicate minerals and fall into two main categories: chondrites, ancient space rocks that date from the beginning of the Solar System, and achondrites, which do not contain chondrules – tiny grains – and come from Mars, the Moon or asteroids.

IRON

These are made mainly of iron-nickel metal and come from the cores of ancient asteroids that melted in the heat of the early Solar System. Their metal cores can sometimes be encased in minerals and have a crust, similar to the structure of terrestrial planets.



STONY-IRON

Stony-iron meteorites are more or less equal parts metal and rock and may have gemstone inclusions. Some can be particularly beautiful – when cut and polished, the olivine crystals inside allow light to pass through in stunning shafts of green and gold.

x3 © Alamy

Right: If a large object survives its fall through the atmosphere, it can leave a lasting impression

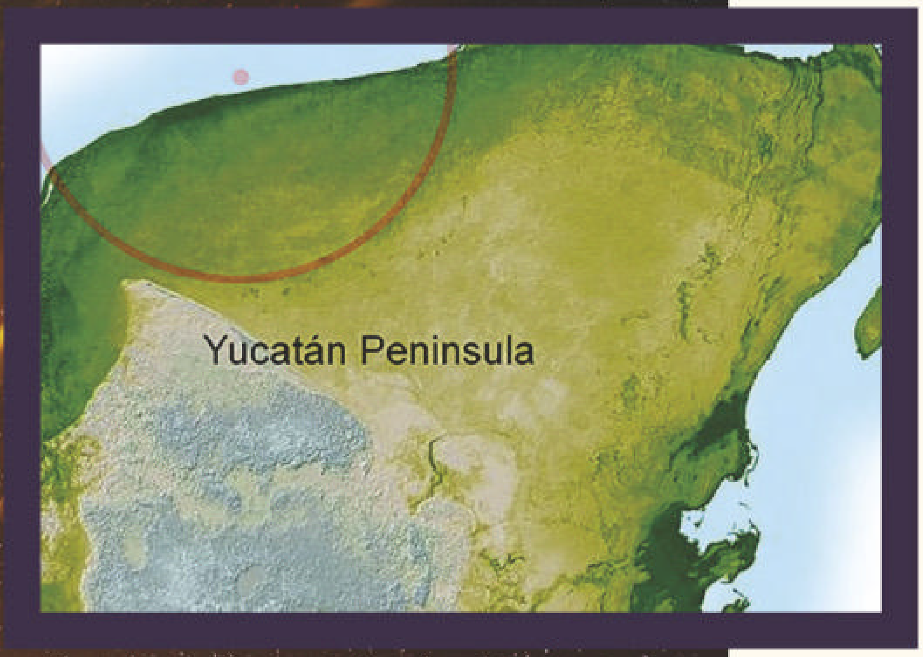
© Alamy

Our planet is a big place, with a surface area of around 510 million square kilometres (197 million square miles), 71 per cent of which is covered by water. Only a tiny fraction of this is covered by cities and urban areas, equating to less than one per cent of the world's landmass - and that figure doesn't include Antarctica, which is pretty much uninhabited anyway. Coincidentally, Antarctica happens to be a great place for hunting meteorites because slow-moving glaciers tend to gather them up at one end like a natural conveyor belt, plus they're easy to spot in the snow. It's been estimated that for every meteorite fall that someone witnesses, another 770 land unseen in uninhabited wilderness or, more likely, disappear into the ocean somewhere. Just 95 witnessed events have been recorded in the last century.

So if the odds of a meteorite striking you on its passage to Earth are astronomical, and you're not likely to be killed by it even if one does, what about being killed by the impact event? Meteorites release huge energies when they hit Earth, depending on their velocity, density, diameter and their angle of entry. We're talking about explosions that can have destructive power orders of magnitude more than the biggest nuclear weapons humankind has detonated. The 2013 Chelyabinsk superbolide event, for example, which exploded in the air over a Russian city and sent thousands of fragmentary meteorites to Earth, wasn't even that big in the grand scheme of things. It was estimated to be around 20 metres (66 feet) wide and weighed around 10,000 tonnes, yet it exploded with the power of up to 33 Hiroshima atomic bombs, equivalent to around 500,000 tonnes of TNT. No one died, though around 1,500 people sought medical treatment for the indirect effects of the explosion, mostly due to flying glass after the shock wave shattered hundreds of window panes.

Chelyabinsk was a once-in-a-lifetime event, while bigger impacts are even rarer. The 50-metre (164-foot) iron meteorite that slammed into the Arizona badlands 50,000 years ago with the energy of a ten-megatonne bomb, creating the 1.2-kilometre (0.7-mile) Barringer crater, only occurs an average of once every 6,000 years. If a meteorite like that hit the city you live in, chances of survival are slim if you live near the epicentre. If a dino-killer like the

> "JUST 95 WITNESSED EVENTS HAVE BEEN RECORDED IN THE LAST CENTURY"



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Above: The crater formed by the impact that killed the dinosaurs is partially underwater, which is why it was only identified by accident in 1990

Left: Luckily the biggest impacts are even rarer, so we likely don't face extinction by meteor

ODDS OF BEING KILLED BY...

LIGHTNING STRIKE	1 IN 180,746
EARTHQUAKE	1 IN 159,890
FLOOD	1 IN 94,481
TORNADO	1 IN 60,000
LOCAL METEORITE IMPACT	1 IN 1,600,000

impactor that created the 150-kilometre (93-mile) Chicxulub crater in Mexico was going to hit Earth tomorrow, then we're all in trouble: everyone in a 5,000 kilometre (3,100 mile) radius would either be vaporised, drowned in a towering tsunami or buried under tonnes of debris. The rest of us would face natural disasters and extreme climate change on a scale we haven't experienced as a species. But such massive impacts are so impossibly rare - maybe one event in 100 million years or more on average - that they're not worth considering. To the best of NASA's knowledge, no large object bigger than one-kilometre (0.62-miles) wide will come close enough to threaten Earth for several hundred years.

Ben Biggs
Editor, How It Works magazine
Ben is the former editor of **All About Space** and is currently editor of **How It Works**. He has been reporting on science and tech for over ten years.

Right: Most objects that enter Earth's atmosphere are the size of a grain of sand or smaller and never reach the ground, burning up as shooting stars

© Getty

GALAXY PROFILE

The Milky Way

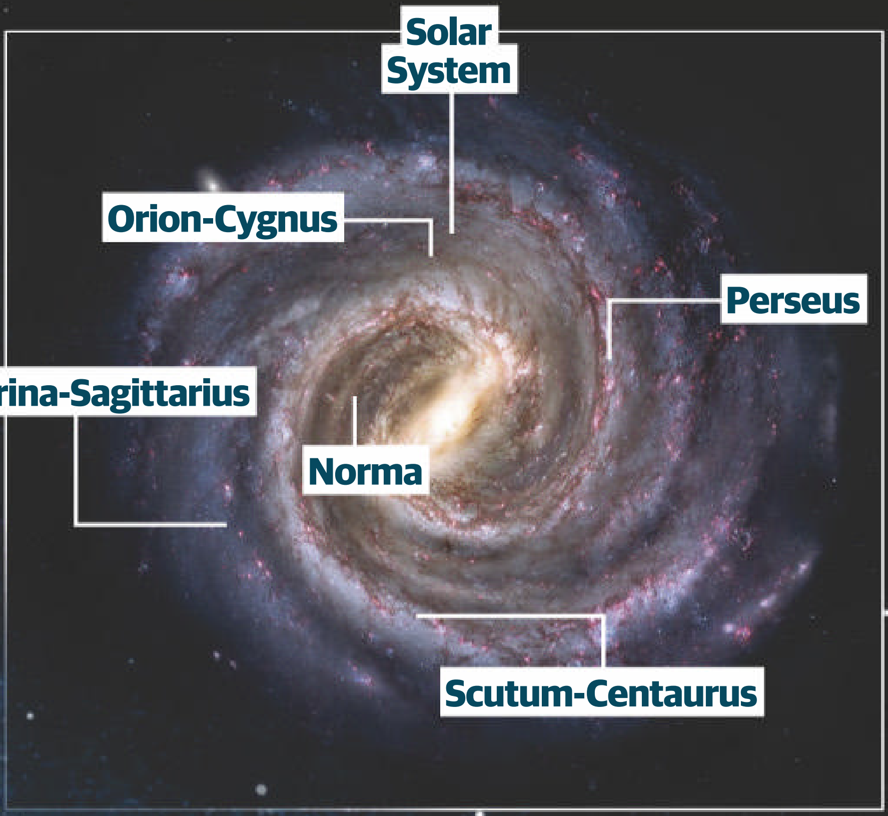
Our galactic home is constantly surprising us, and it hasn't finished yet

The Milky Way is a barred spiral galaxy with large pivoting arms stretching out across the cosmos. Our Solar System is about 25,000 to 30,000 light years from the centre. Life in the outskirts is good. We find ourselves nestled in one of the smaller neighbourhoods, the Orion-Cygnus Arm, sandwiched between the larger Perseus and Carina-Sagittarius arms. If we were to travel inwards towards the centre we would find the Scutum-Centaurus and Norma arms. On a clear night devoid of light pollution, we can catch a glimpse of the bright lights of the galaxy streaking across the night sky. Our window into the universe, this milky-white band of stars, dust and gas is where our galaxy gets its name.

The Milky Way disc is about 100,000 light years wide and 1,000 light years thick. If you wanted to view the entire galaxy with your own eyes, you would need to travel about 36,000 light years out from Earth. Just as Earth orbits the Sun, the Solar System orbits the centre of the Milky Way. Despite hurtling through space at speeds of around 828,000 kilometres (515,000 miles) per hour, it still takes our Solar System around 250 million years to complete a single revolution. The last time our planet was in this position, dinosaurs were just emerging.

© Getty

> “DESPITE HURTLING THROUGH SPACE, IT STILL TAKES OUR SOLAR SYSTEM AROUND 250 MILLION YEARS TO COMPLETE A SINGLE REVOLUTION”



© NASA

COMPOSITION

100 BILLION STARS
AND COUNTING

MOST COMMON STAR
RED DWARFS

4 MILLION SUNS
SUPERMASSIVE BLACK HOLE SAGITTARIUS A*

Lying at the very heart of the Milky Way is a supermassive black hole, Sagittarius A*. 4 million times the mass of the Sun, it consumes anything that strays too close, gorging on an ample supply of stellar material enabling it to grow into a giant. Though we cannot directly view this glutton at the core of our galaxy, scientists can infer its presence by investigating its effect on nearby matter. We are constantly building on our wealth of knowledge of the Milky Way, though up until relatively recently astronomers believed that all the stars in the sky belonged to our galaxy.

The Great Debate in 1920 saw astronomers Heber Curtis and Harlow Shapley argue the scale of the universe and the prospect of ‘island universes’. On one side of the debate, Shapley believed the Milky Way was much larger than previous estimates, and that we weren’t at the centre. He also claimed that ‘spiral nebulae’, such as Andromeda, were part of the Milky Way.

On the other side of the debate, Curtis did not dispute Shapley’s claims of a far larger Milky Way. He did, however, argue that there were large island universes, such as Andromeda, that lay beyond the boundaries of the Milky Way. The dispute was resolved when Edwin Hubble’s measurements of Cepheid variable stars proved Andromeda was in fact located far outside the Milky Way. Modern estimates suggest the Andromeda Galaxy, our nearest galactic neighbour, is about 2.5 million light years away.

We now know that the Milky Way resides within the Local Group of galaxies, made up of over 30 galaxies including Andromeda, Triangulum and Leo I. It turns out that it’s pretty good to know who your neighbours are, as they may be closer than you think. The Milky Way is currently hurtling towards Andromeda at 400,000 kilometres (250,000 miles) per hour, though there’s no need to worry just yet - this crash of cosmic proportions is not due for another 4.5 billion years.

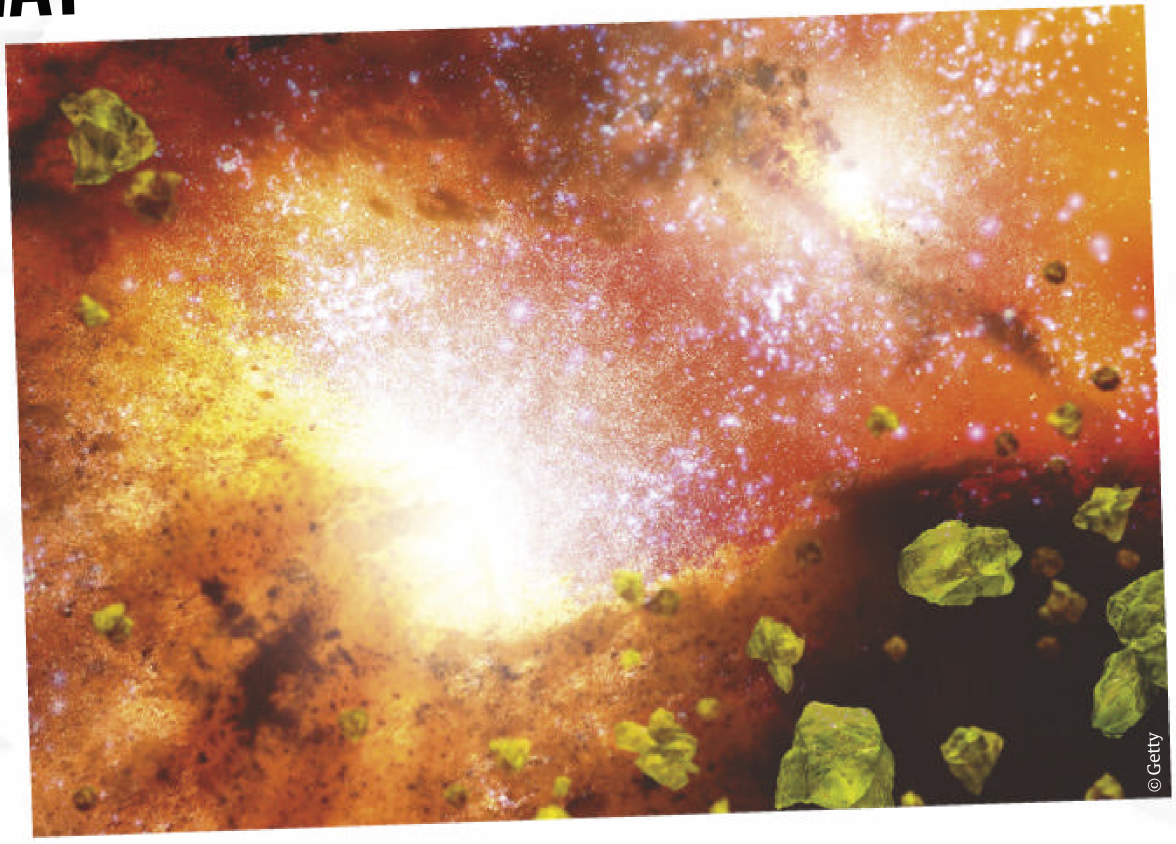
NEWS FROM THE MILKY WAY

A colossal collision

While the Milky Way contains over 100 billion stars, not every stellar origin story starts here. Many were once part of different galaxies that found themselves on a collision course with our galactic home. When smaller galaxies strayed too close, our Milky Way proceeded to devour them and engulf their stars into the iconic spiral we see today.

The Milky Way has collided with many galaxies over its lifetime, but up until recently, one of the oldest and largest mergers had remained undetected. Through the application of artificial intelligence using data supplied by the Gaia space probe, researchers have been able to group clusters of stars in the Milky Way by their age, motions and chemical composition. In doing so they have found evidence of five large-scale galactic mergers. The findings were published in the October 2020 issue of the journal *Monthly Notices of the Royal Astronomical Society.*

One merger of particular importance has been dubbed 'the Kraken'. This collision is estimated to have taken place about 11 billion years ago, when the Milky Way was just a fraction of its current size. This makes the Kraken the oldest and largest galactic merger that we have discovered in the Milky Way's 13.6-billion-year history.



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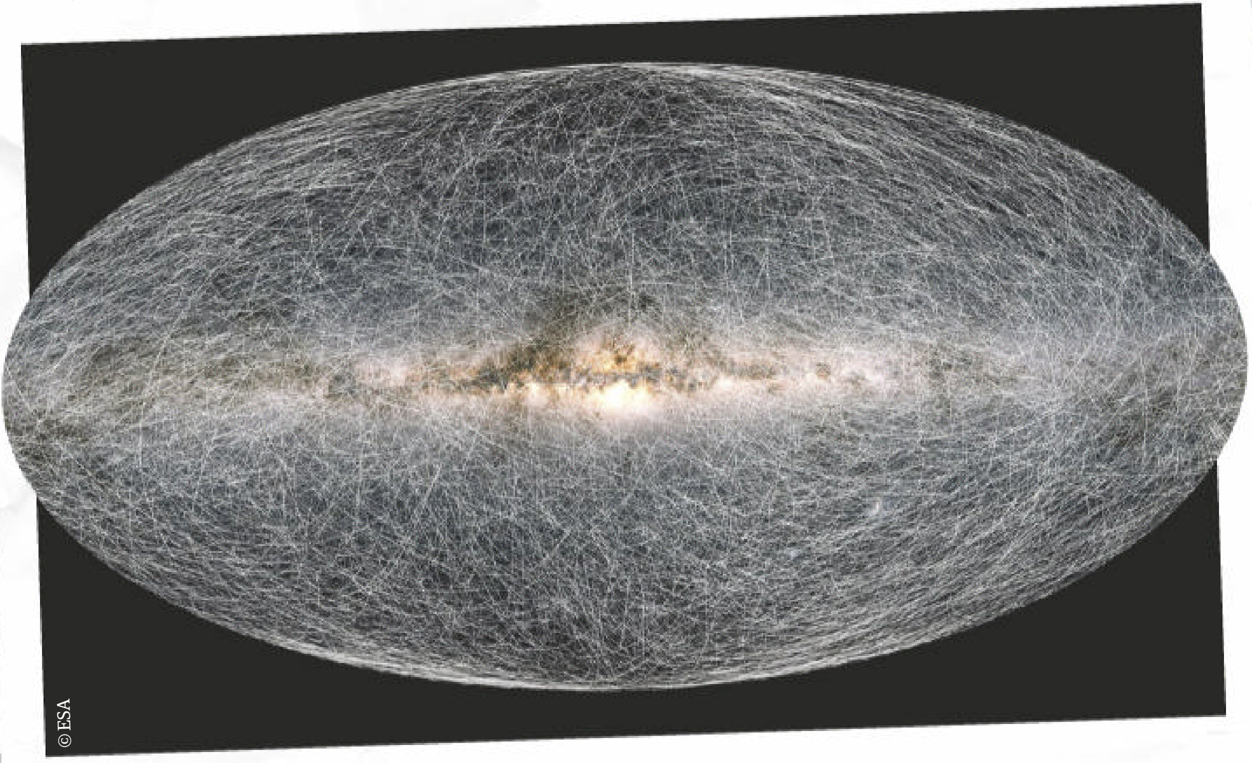

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Celestial treasure trove

In December 2020 the European Space Agency (ESA) announced the third and largest data release from the Gaia mission, which included information on 1.8 billion sources in the Milky Way. Gaia has spent over six years observing the cosmos with a primary focus on cataloguing and monitoring the stars of the Milky Way while constructing a detailed 3D map. The spacecraft has been fundamental in our understanding of the Milky Way, and if the previous data releases are any indication, this third release will no doubt reveal considerably more.

Astronomers have already used some of this newly released data to identify populations of stars all the way out to the furthest reaches of the Milky Way, producing a new census of stars in our solar neighbourhood – 331,312 of them, to be precise. But that's not all. The novel data has also revealed that the Solar System's orbit around the Milky Way is accelerating, causing a deflection in the trajectory of the Solar System equating to about 115 kilometres (71 miles) a year.

Got gas? Not anymore!

We are not alone in our galactic neighbourhood – some 60 or so other known satellite galaxies swing by every now and then. The largest of these are the Large Magellanic Cloud and Small Magellanic Cloud, which are both visible in the sky from the Southern Hemisphere. However, not all of these galaxies shine bright. Dwarf spheroidal galaxies, for example, emit just 0.0005 to 0.1 per cent as much light as our Milky Way. However, research published online in October 2020 suggests that their existence wasn't always so dim.

Using data from the European Space Agency's Gaia spacecraft, scientists have found a more sinister reason for dwarf spheroidals' faint, ghostly appearance. These galaxies once lit up with a flurry of star formation when they first crossed into our galaxy's gravitational territory. Though this hive of activity did not last very long, as the Milky Way began to strip these vulnerable galaxies of gas. Starving them of the fuel needed to make new stars, the Milky Way snuffed out their light and stunted any further growth and development.

© ESO

FUTURE EXPLORATION OF THE MILKY WAY

NASA has selected an ambitious mission to measure emissions from the cosmic material lurking between stars. The Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory (GUSTO) mission, led by Dr Christopher Walker from the University of Arizona, aims to unravel the complexities of the interstellar medium.

The mission will use a balloon to carry a telescope equipped with carbon, oxygen and nitrogen emission-line detectors to observe the cosmos like never before. The mission won't be using just any old balloon – it'll be using an Ultra Long Duration Balloon (ULDB), which looks like a giant pumpkin and can remain in the air for between 100 and 170 days, weather permitting.

The pressurised pumpkin will be completely sealed and able to maintain a constant altitude both day and night, which will make for more accurate data collection. The unique combination of data collected from GUSTO will greatly advance our understanding of the stellar life cycle, from nebulae formation to the birth and death of stars. It will also map out large sections of the Milky Way and the Large Magellanic Cloud.

Scientific advancements such as GUSTO would not be possible without the support of NASA's Explorers Program, which launched its first mission in 1958 and has been involved in over 90 missions since. The Explorers Program is designed to help make space more accessible by pioneering frequent flight opportunities for scientific investigations.

GUSTO is now in its final phase, whereby finishing touches, testing and launch preparations are being made. Despite the progress, we will have to wait until December 2021 for the launch of the $40 million (£29 million) mission from Antarctica.

Below: GUSTO will tell us more about stellar life cycles and the space between stars

© NASA

THE MILKY WAY BY NUMBERS

250
MILLION YEARS
The time it takes for our Solar System to make one full revolution of the Milky Way

13.6
BILLION YEARS
The age of the Milky Way

1,000
LIGHT YEARS
The thickness of the Milky Way's disc

1.5
TRILLION SOLAR MASSES
The mass of the Milky Way

90%
The proportion of the Milky Way that is dark matter

26,000
LIGHT YEARS
How far our Solar System is from the galactic centre

4.5
BILLION YEARS
Time until the Milky Way and Andromeda galaxies collide

THE EVOLUTION OF THE MILKY WAY

Date: 1 billion years
Activity: The inner halo and bulge of the Milky Way begin to form from a gas cloud with low angular momentum.

Date: 2.8 billion years
Activity: The Milky Way merges with the Kraken galaxy. This collision is considered the largest galactic collision the Milky Way ever experienced.

Date: 3.8 billion years
Activity: The Milky Way experiences a stellar 'baby boom'. Stars were produced 30-times faster than today.

Date: 4.8 billion years
Activity: Milky Way merges with the Gaia-Enceladus galaxy.

Date: 5 billion years
Activity: Formation of a small disc stretching out from the central bulge of the Milky Way. The disc begins to grow 'inside out', with the central region forming first. The rotation of the disc increases in momentum, causing the gas clouds to collapse along the rotational axis and forming a relatively flat disc.

Date: 9 billion years
Activity: The Milky Way disc begins to grow, and the outer regions of the disc form.

Date: 9.2 billion years
Activity: Our Sun and Solar System begin to form.

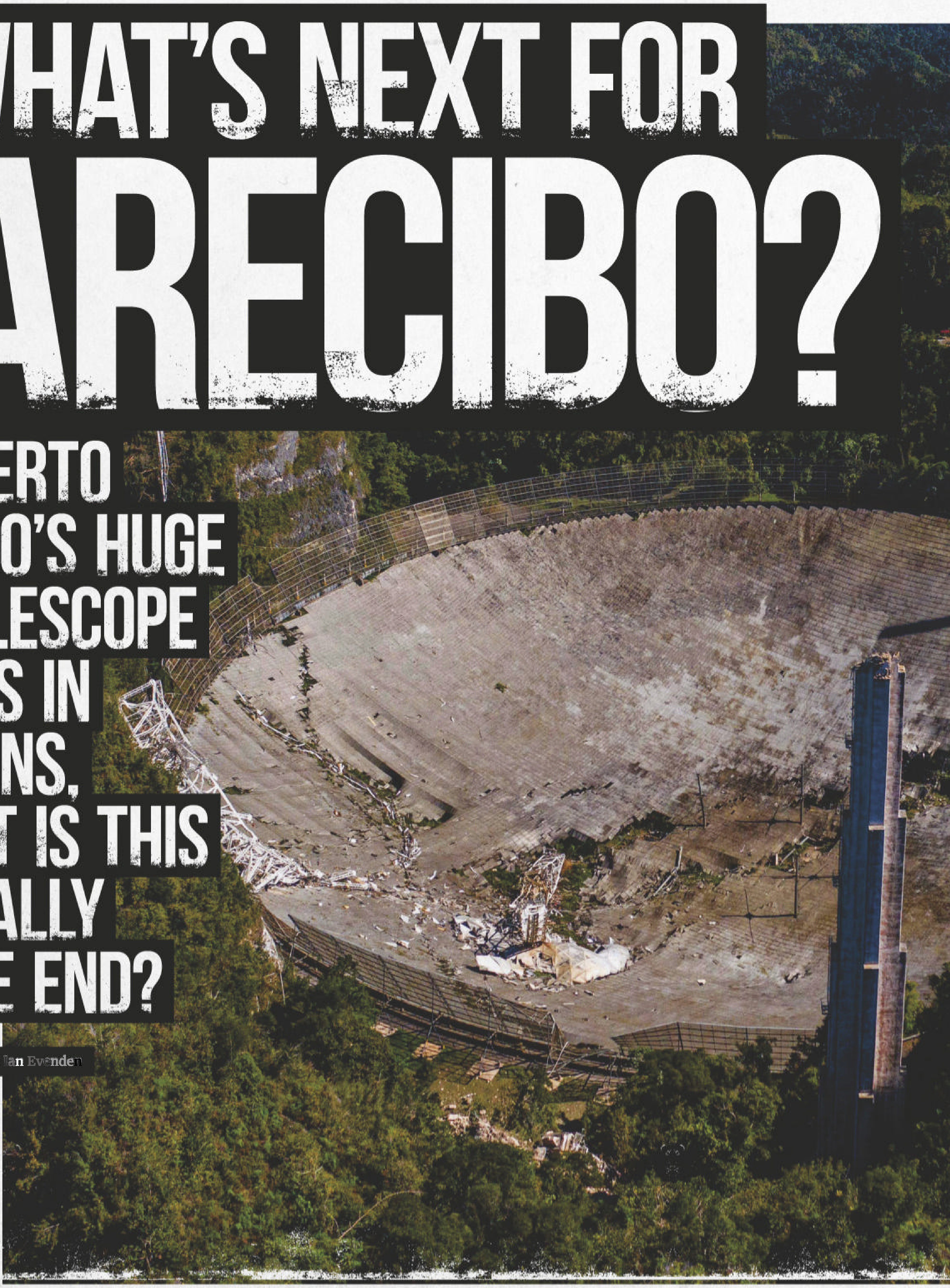
Date: 10.1 billion years
Activity: Life on Earth begins, shortly after the Late Heavy Bombardment.

Date: 13.6 billion years
Activity: Outer regions of the galactic disc continue to form. It is not currently fully understood why stellar formation in the disc is still in an active phase.

WHAT'S NEXT FOR ARECIBO?

PUERTO RICO'S HUGE TELESCOPE LIES IN RUINS, BUT IS THIS REALLY THE END?

Reported by Ian Evenden



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After almost 60 years, it looks like time to say goodbye to the iconic Arecibo telescope. The dish, which reclined in a sinkhole on the Caribbean island of Puerto Rico, was just too badly damaged when its support cables snapped following earthquakes and hurricanes. If it cannot be repaired, then what does the future hold for the observatory? "The damage to the telescope cannot be repaired," says Rob Margetta of the National Science Foundation (NSF), the body that administers the telescope in partnership with the University of Central Florida. "It suffered extensive damage due to the 2020 collapse. The telescope's instrument platform was also a complete loss, and its support towers were damaged." That statement seems pretty final, but there are other instruments at Arecibo that haven't been damaged. Plans for a replacement are at an early stage, and there are other telescopes around the world that can carry on its pioneering work.

"Arecibo Observatory has other facilities that the NSF seeks to bring back online as soon as possible," says Margetta. "The NSF has instructed the University of Central Florida, the operator of Arecibo, to repair its LIDAR facility's roof and its 12-metre (39-foot) telescope. Additionally, researchers will continue to work utilising archived data from the 305-metre (1,000-foot) telescope.

"The collapse of the telescope at Arecibo Observatory is a great loss to the astronomy community," Margetta continues. "It will take some time to assess how the community will compensate. The NSF is confident in the resilience of the astrophysics community, and will encourage other facilities it funds to work directly with Arecibo scientific investigators and provide them with the necessary support."

Funding is crucial to the observatory's future. When the 91-metre (300-foot) telescope at Green Bank Observatory in West Virginia collapsed in 1988 with no warning – and thankfully no injuries – the plan to replace it had the support of two powerful senators, who could push through funding. In its place rose the world's largest fully steerable radio telescope, part of a larger observatory complex at the heart of a radio-quiet zone to enhance its ability to sense faint signals from the deep sky.

As Puerto Rico is an unincorporated US territory and not a state, it doesn't have any senators to lobby for it. There's also some bureaucracy at

WHAT HAPPENED TO ARECIBO?

Arecibo was built in a geologically active and hurricane-prone area. The 900-tonne receiver platform, supported by cables from concrete support towers, was particularly vulnerable. It shrugged off many meteorological excesses, but in 2017 Hurricane Maria caused the 430 MHz line feed to break and fall onto the primary dish, damaging roughly 30 of the 38,000 aluminium panels. Following Hurricane Isaias in August 2020, an auxiliary platform support cable separated from Tower 4, causing a 30-metre (98-foot) gash in the dish. Plans were made to replace all six auxiliary cables. However, in November, before repairs could be carried out, one of the two main support cables from Tower 4 snapped, shattering part of the dish itself as it fell. It was announced on 19 November that the dish would be decommissioned, and the receiver platform finally collapsed into the dish on 1 December 2020.

WHERE CAN ARECIBO'S SCIENCE BE MOVED TO?

PULSAR DETECTION

One of Arecibo's earliest discoveries was the periodicity of the Crab Pulsar in 1968. Since then it has discovered many more, including mysterious 'part-time' pulsars that appear to switch on and off.

GREEN BANK OBSERVATORY

Having already discovered three millisecond pulsars and the most massive neutron star ever detected, Green Bank hosts the world's largest fully steerable radio telescope.

© NRAO

PLANETARY DEFENCE

The mission to spot and track near-Earth asteroids – and decide whether they are a threat – was one that Arecibo excelled at. There is no immediate replacement with the same capabilities.

VERA C. RUBIN OBSERVATORY

This will include the Simonyi Survey Telescope, which will catalogue 90 per cent of near-Earth objects larger than 300 metres (984 feet) and assess their threat level.

© LSST

SETI

Arecibo was famous for its involvement with the Search for Extraterrestrial Intelligence and its transmission of the Arecibo message, a binary representation of Earth and its life, towards globular cluster Messier 13.

ALLEN TELESCOPE ARRAY (ATA)

The first array designed with SETI in mind, the Allen Telescope Array is made up of 42 dishes. It has a wide field of view and wide frequency coverage, perfect for picking up alien signals.

© SETI

work regarding who would pay. Ground-based installations in the US are the responsibility of the NSF and its partners, while the ones in space belong to NASA, which pays for observation time on the Earth-based instruments and even operates one in California, called Goldstone, to communicate with spacecraft. There is likely to be military interest too, following the founding of the US Space Force in 2019, and the importance of tracking launches and satellites to that agency.

The structure was already earmarked for demolition - before it took matters into its own hands - due to the amount of damage it had suffered due to its support cables breaking. "It is a hard thing to have to take down an iconic facility like this that's provided so much for the radio astronomy and planetary radar community over so many decades. It's really sad to see," said Lindley Johnson, head of NASA's Planetary Defense Coordination Office, during a meeting of NASA's Planetary Advisory Committee in November 2020. "It's certainly not an ideal situation, but it's time to really get moving on investing in a new planetary radar capability." Arecibo would collapse the very next day, robbing the world of its most powerful planetary radar facility.

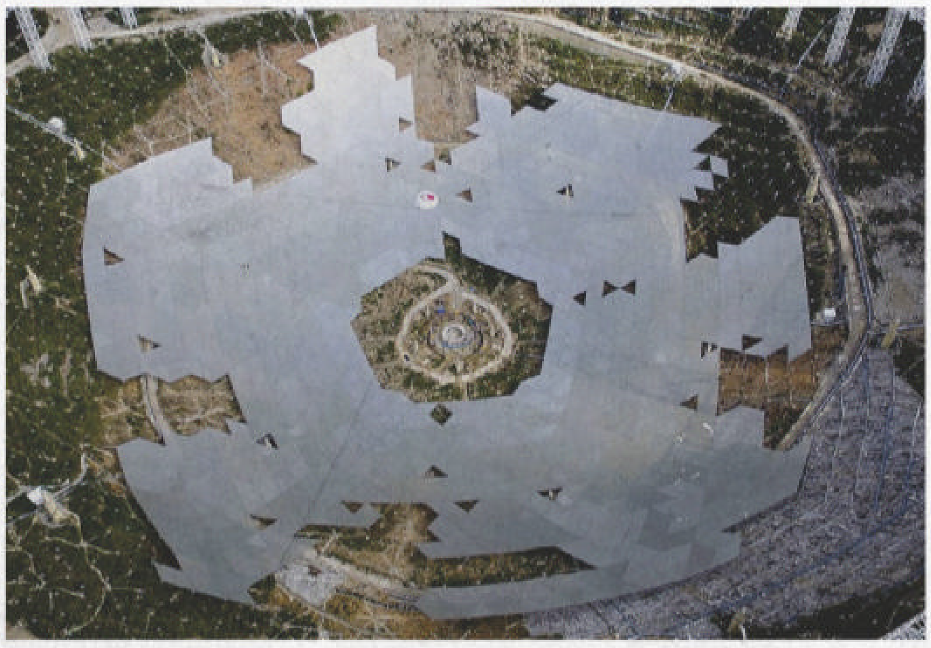
If a coalition can be put together to pay for it, just as Arecibo came out of a partnership between the Department of Defense and Cornell University, what would it look like? A white paper delivered to the NSF in December 2020 was ambitious: a 300-metre (984-foot) platform bridging the sinkhole and covered in 1,000 individual nine-metre (29.5-foot) dishes. These wouldn't be independently steerable, but the platform would be outfitted with hydraulics that could tilt it more than 45 degrees, bringing the supermassive black hole at the centre of our galaxy within its view. A thousand transmitters would be more powerful than the single transmitter they replaced, and this next-generation Arecibo could be twice as sensitive as the original.

Every ten years, however, a large elephant enters the room. The Astronomy and Astrophysics Decadal Survey is produced every ten years by the National Research Council of the National Academy of Sciences in the US, and tends to set the priorities for funding from the NSF and Congress. Arecibo couldn't have collapsed at a worse time, as the 2020 survey is just about to report back, setting the priorities for the next decade. Bringing in private donors is a possibility, and at the end of 2020, Puerto Rico's outgoing governor Wanda Vázquez Garced allocated $8 million (£5.8 million) to clean up the site and begin a feasibility study for a new dish, saying it was a "matter of public policy" that the observatory be rebuilt. A report to Congress on the damage to the site and plans for preservation and re-establishment of 'comparable technology' on Puerto Rico is also pending.

None of this will happen fast enough for the scientists who relied on Arecibo for their work, however. The only other planetary radar is the Goldstone facility in California, and although it was recently upgraded, it's still not as powerful as

MEET FAST: ARECIBO'S REPLACEMENT

CHINA'S GIANT RADIO TELESCOPE COULD CARRY ON ARECIBO'S PIONEERING WORK



Right: The huge dish was assembled piece by piece, becoming the largest radio telescope in the world

x2 Images © Getty

Arecibo, plus it's part of the Deep Space Network and does work for the military, so has added pressure on its time. The huge dish on Puerto Rico may have been operating since 1963, but it was far from obsolete thanks to its size and the upgrades it had received in the intervening decades. Arecibo played an important role in planetary defence, spotting near-Earth asteroids and estimating their size and orbit to gauge whether they were a danger to civilisation. Arecibo's powerful transmitter and large receiving dish could spot asteroids other telescopes would miss, its radar offering additional details about the composition of a space rock, and whether it's one or two objects.

Under construction in Chile, however, is a telescope that will finally outdo Arecibo in the spotting of near-Earth objects. The Vera C. Rubin Observatory has an 8.4-metre (27.5-foot) wide-field reflecting telescope that will be able to photograph the entire night sky. It's expected to expand the number of small near-Earth objects known by 10 to 100 times along with its other aims of studying dark matter, mapping the Milky Way and detecting transient phenomena such as supernovae and gamma-ray bursts. While first light at the telescope was anticipated to be in 2021, the COVID-19 pandemic has brought a halt to construction at the site on the El Peñón peak of Cerro Pachón, a mountain in northern Chile. Work on its software continues, however.

Other observatories across the world have been quick to offer themselves as replacements for at least part of Arecibo's capabilities. One of these was the Five-hundred-meter Aperture Spherical Telescope (FAST) in southwest China, which is similar in construction to the Arecibo dish, set in a natural basin in the landscape. Its design is slightly

Right: **One of the smaller radio telescopes which is still functioning at the Arecibo Observatory**

© Alamy

> "THE COLLAPSE OF THE TELESCOPE AT ARECIBO OBSERVATORY IS A GREAT LOSS TO THE ASTRONOMY COMMUNITY" ROB MARGETTA

1 LOCATION
The scope sits in a natural sinkhole in Pingtang County, Guizhou, China.

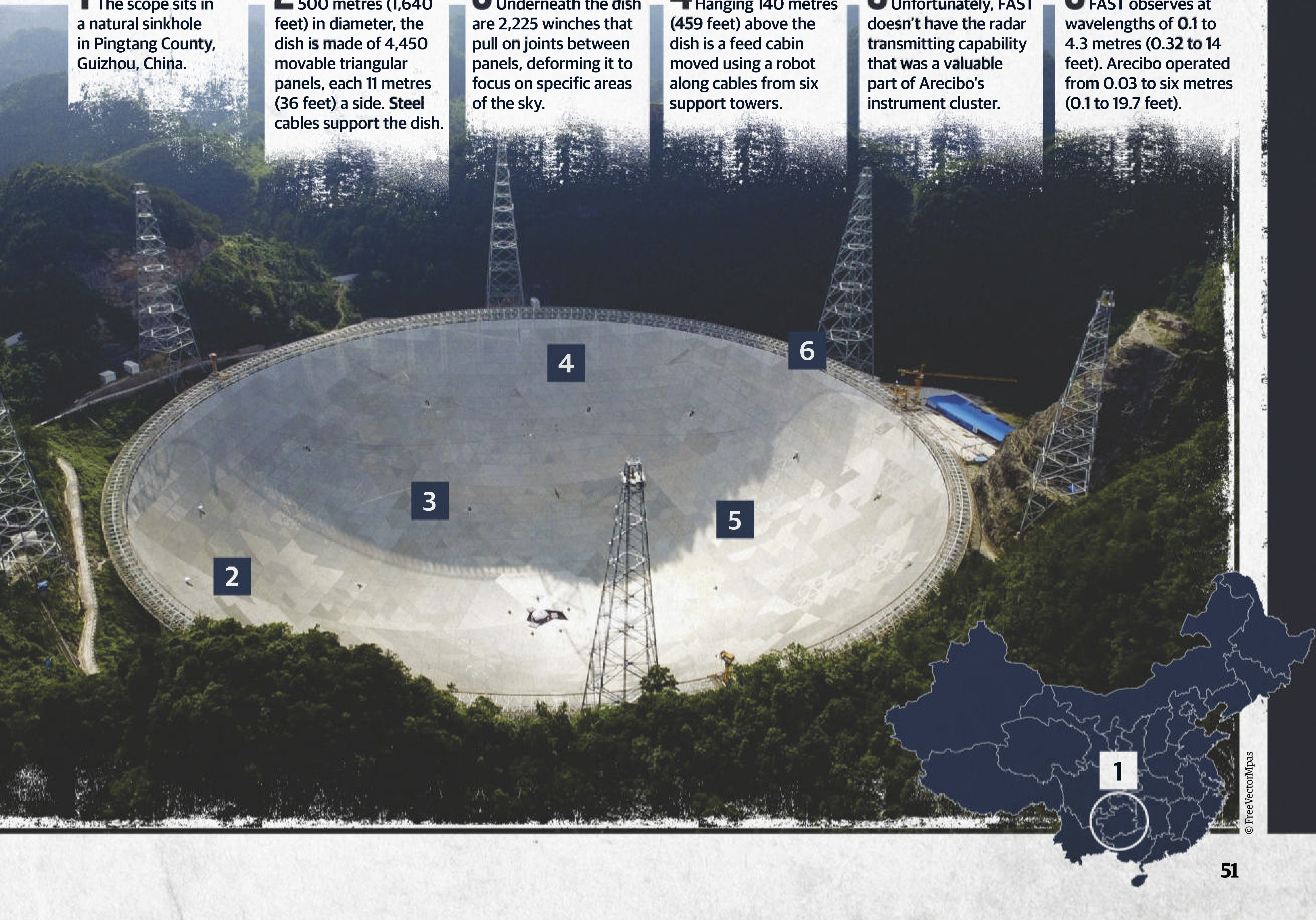
2 DISH
500 metres (1,640 feet) in diameter, the dish is made of 4,450 movable triangular panels, each 11 metres (36 feet) a side. Steel cables support the dish.

3 WINCHES
Underneath the dish are 2,225 winches that pull on joints between panels, deforming it to focus on specific areas of the sky.

4 ROBOT
Hanging 140 metres (459 feet) above the dish is a feed cabin moved using a robot along cables from six support towers.

5 RADAR
Unfortunately, FAST doesn't have the radar transmitting capability that was a valuable part of Arecibo's instrument cluster.

6 WAVELENGTHS
FAST observes at wavelengths of 0.1 to 4.3 metres (0.32 to 14 feet). Arecibo operated from 0.03 to six metres (0.1 to 19.7 feet).



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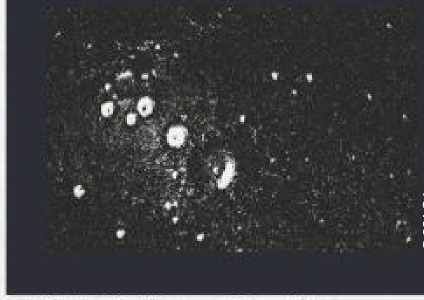
ARECIBO'S BEST BITS

MAPPING ASTEROIDS

Using its ability to send out radar signals, Arecibo imaged many near-Earth asteroids. It discovered that they often orbit in pairs or trios, rather than being lone rocks hurtling through space.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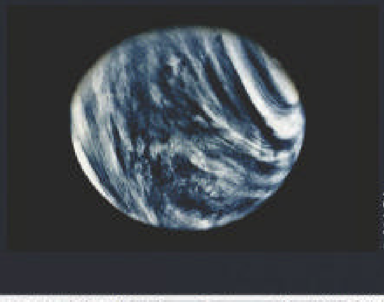
CUTTING THROUGH VENUS' CLOUDS

The powerful radar at Arecibo could see into places nothing else could. It produced images of the surface of Venus we could never see any other way due to the planet's thick, opaque atmosphere.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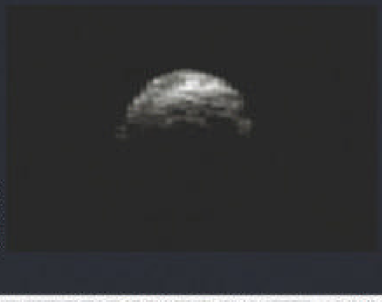
ROTATION OF MERCURY

In 1964, Arecibo was able to determine that the rotation period of Mercury was 59 days instead of the previously believed 88 days. This proved that it was not tidally locked to the Sun.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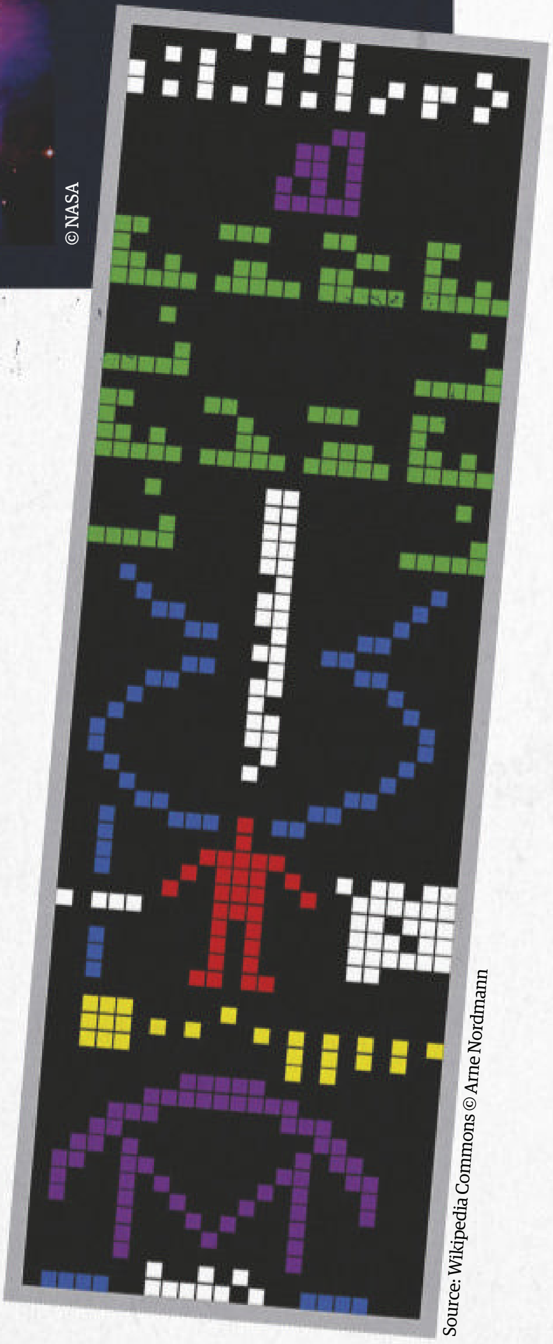
THE CRAB NEBULA PULSAR

Studying this pulsar in 1968, Arecibo was able to time its pulses at 33 milliseconds. This was faster than what was expected, and was the first solid evidence for the existence of neutron stars.

© NASA

A MESSAGE TO THE STARS

A binary message designed to be decoded by an alien civilisation, the Arecibo message was sent in the direction of globular cluster Messier 13, about 25,000 light years away, in 1974.


Source: Wikipedia Commons © Arne Nordmann

different though, with both a tilting surface and a mobile receiver. It is up to three times as sensitive as Arecibo, and is surrounded by a similar radio-silence zone as Green Bank.

"Our scientific committee aims to make FAST increasingly open to the international community," Wang Qiming, the chief inspector of FAST's operations and development center, said in a statement. When asked about Arecibo, Wang admitted there was a similarity: "We drew a lot of inspiration from its structure, which we gradually improved to build our telescope." FAST has already discovered many pulsars, a mainstay of the research at Arecibo, but will not be able to detect near-Earth asteroids as the powerful transmitters required are too heavy for its small receiver cabin. In 2016, FAST joined the Breakthrough Listen SETI program to help detect any signals coming from intelligent alien civilisations.

Another candidate is the Russian RATAN-600, which is a 576-metre (1,889-foot) circle of radio reflectors rather than a solid dish. The reflectors are angled to reflect incoming radio waves to either a central secondary mirror or one of five parabolic cylinders, each of which has its own instruments. This makes for a partially steerable array with the power of a nearly 600-metre (1,986-foot) dish, the world's largest single radio telescope. RATAN-600 is largely used to observe the Sun, and it has also contributed to the SETI project. In 2015 it detected a strong signal from HD 164595, a star in the constellation of Hercules with one known planet. It was only observed once, for two seconds, and this failure to repeat means the signal is probably of Earth origin. As its frequency was in a military waveband, a reconnaissance satellite seems the most likely source.

Whatever happens, the astronomical world feels its loss keenly. "Arecibo has helped transform our understanding of the ionosphere, showing us how density, composition and other factors interact to shape this critical region where Earth's atmosphere meets space," says Michael Wiltberger, head of the NSF's geospace section. "While I am disappointed by the loss of investigative capabilities, I believe this process is a necessary step to preserve the research community's ability to use Arecibo's other assets and hopefully ensure that important work can continue at the facility."

Scientists all over the world are looking around for replacement instruments to continue their work. While nostalgia for the past is strong, there's a feeling that Arecibo's work wasn't finished. The observatory "really deserves to have a future, not because of what it has done in the past, but because of what it can keep doing," University of Arizona planetary scientist Alessondra Springmann says. "There's very much an 'anything is possible' mentality there because it's designed to be so flexible; you're not necessarily locked in to only doing a handful of things with it. We can prioritise science – we can decide that we want to make sure that Arecibo lasts into the future."

Whatever is decided in the next few months, Arecibo and its staff can be proud of the contribution they've made to our understanding of the universe. While it was a series of natural disasters that reduced it to its current state, the natural wonders it has discovered will continue to amaze and inspire long into the future.

Ian Evenden
Space science writer
Ian has been writing about the universe for over ten years, focusing on cosmology and space exploration. He's also a keen astrophotographer.

Below: The observatory before the collapse, showing the receiver platform suspended above the main dish

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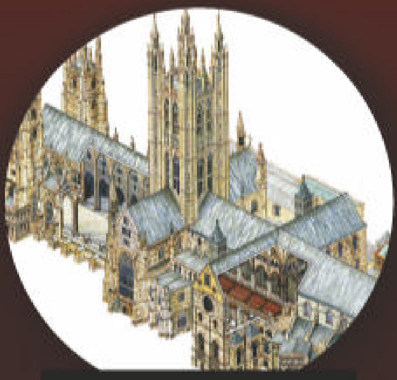
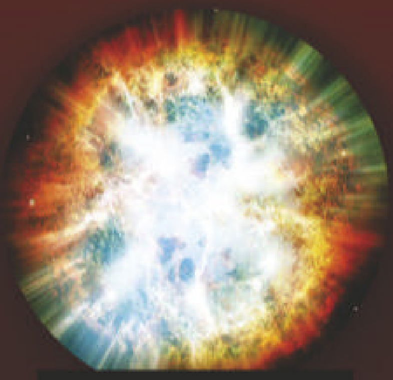


ILLUSTRATIONS



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NEW LAW PROTECTS APOLLO SITES FROM MOON MISSIONS

Future launches to the lunar surface will be required to leave these iconic locations untouched

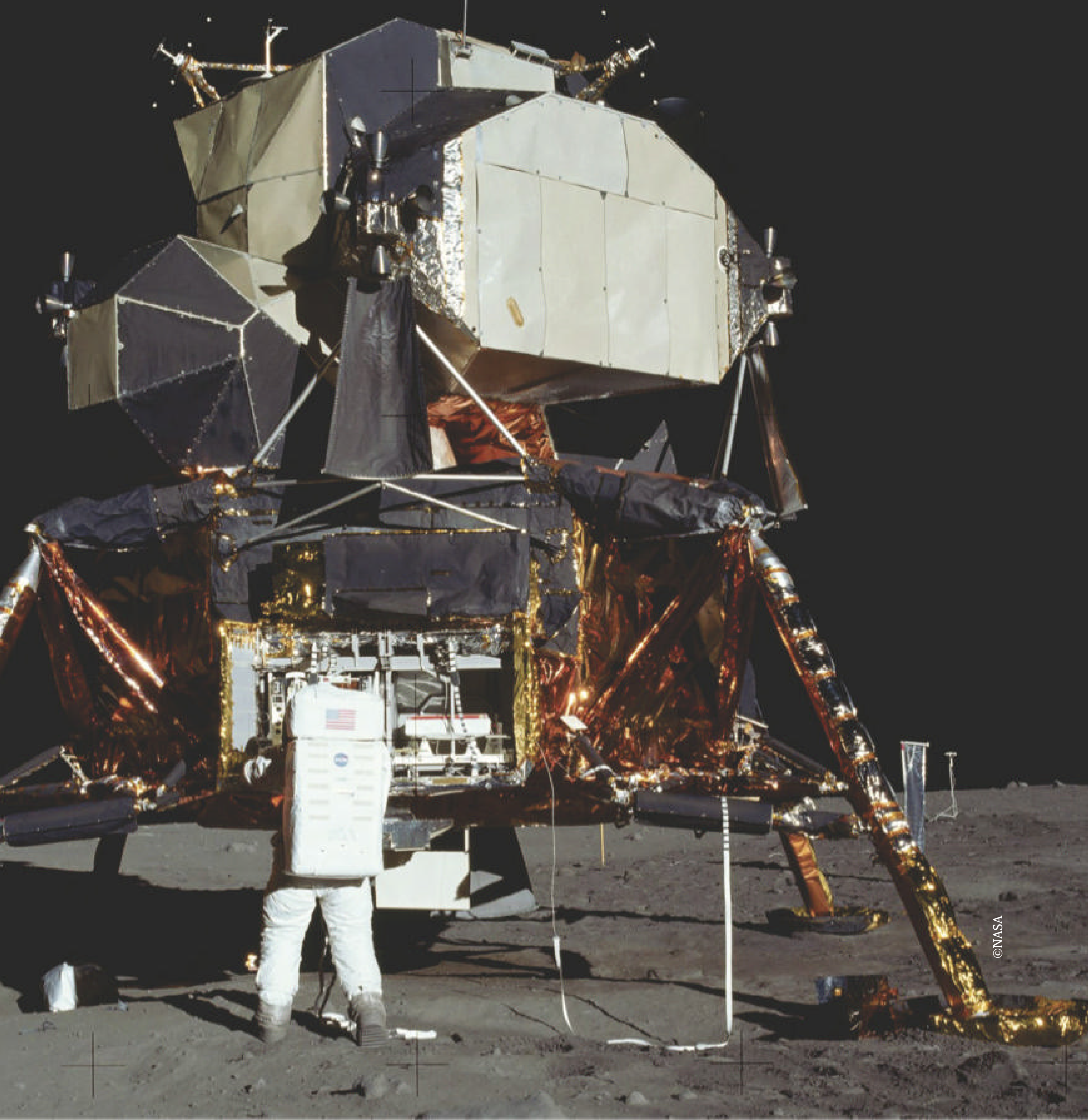
Preserving the historic sites where humans first landed on the Moon is now not only a good idea, it is also the law. The US has enacted its first legislation that requires American companies and other entities working with NASA on new missions to the Moon to avoid disturbing the US hardware that was left there 50 years ago. The 'One Small Step to Protect Human Heritage in Space Act' became law on 31 December.

"I have long advocated for the preservation of the Apollo artefacts, which hold deep cultural, historical and scientific value for not only the US, but for all of humanity," said Eddie Bernice Johnson, chair of the House Committee on Science, Space and Technology. "It is important that NASA and the US lead the way in guiding responsible behaviour in space, and this legislation to preserve our human heritage in space is one small step in practicing that."

The new law directs NASA to require future Moon missions to abide by a set of best practice recommendations drafted in 2011 "to protect and preserve the historic and scientific value of US government lunar artefacts." The recommendations, which until now had been non-binding, address the paths that spacecraft should follow when descending to the lunar surface and define 'keep-out zones' to avoid the purposeful or inadvertent disturbance of the Apollo landing sites. US commercial enterprises and others seeking contracts, grants or other agreements for lunar activities carried out by, for or in partnership with NASA will need to agree to stay clear of the human heritage sites on the Moon to be eligible for the requested support. The law also requires that NASA informs other relevant US federal agencies of the preservation recommendations and encourage their use.

"As we go forward to the Moon with the Artemis Program, NASA has been clear that we must do so sustainably," said NASA administrator Jim Bridenstine. "As part of the Artemis Accords agreements signed with partner nations, NASA has emphasised that protecting historically significant sites is critical, and I applaud the leaders of this legislation for their commitment to ensuring that future lunar science and exploration is done in a safe and transparent manner."

The law applies to companies such as Intuitive Machines, Astrobotic and Masten Space Systems, which have contracts under NASA's Commercial Lunar Payload Services initiative to deliver science payloads to the surface of the Moon. The law also applies to SpaceX, Blue Origin and Dynetics, which are developing human landing systems for the Artemis program.



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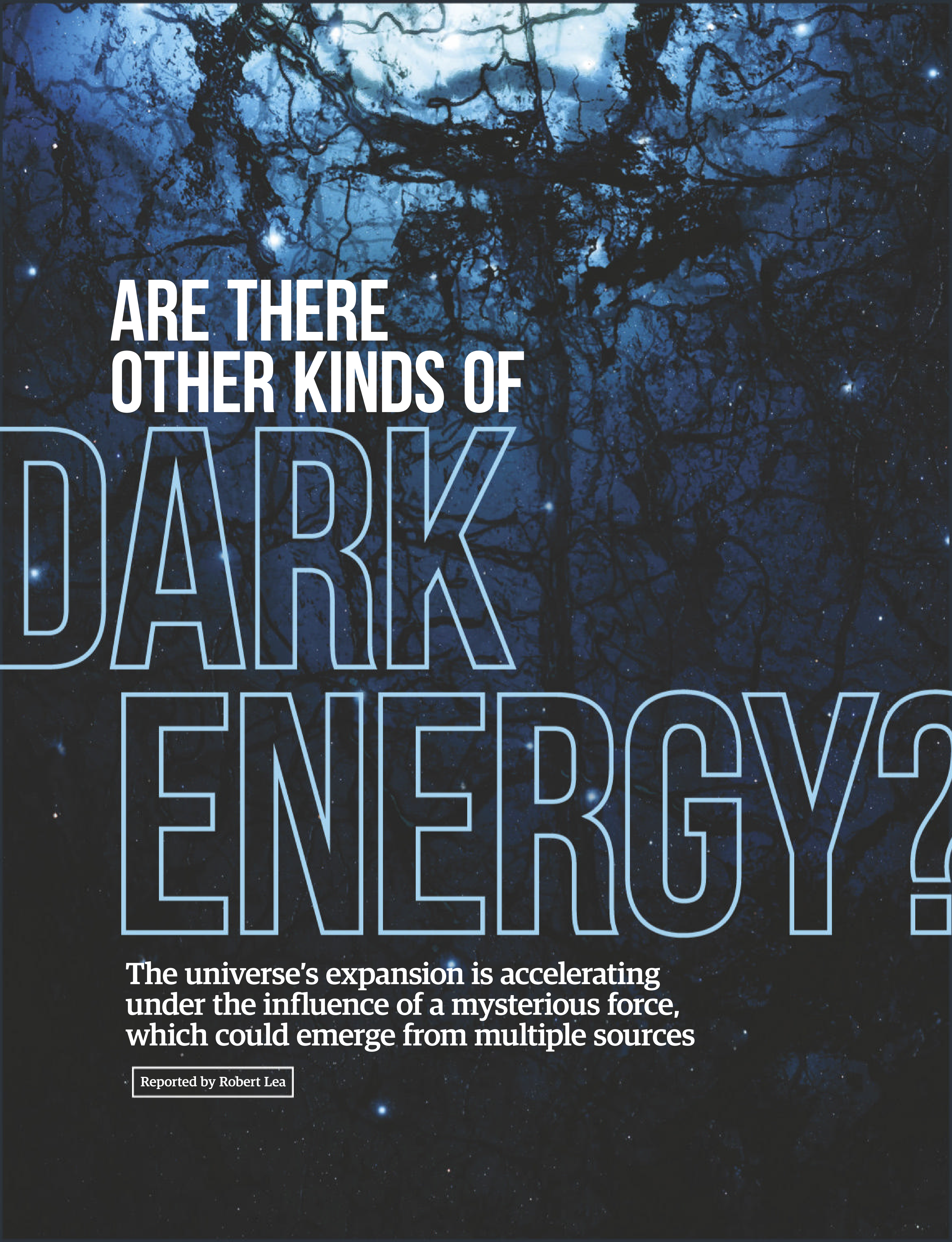


ARE THERE OTHER KINDS OF DARK ENERGY?

The universe's expansion is accelerating under the influence of a mysterious force, which could emerge from multiple sources

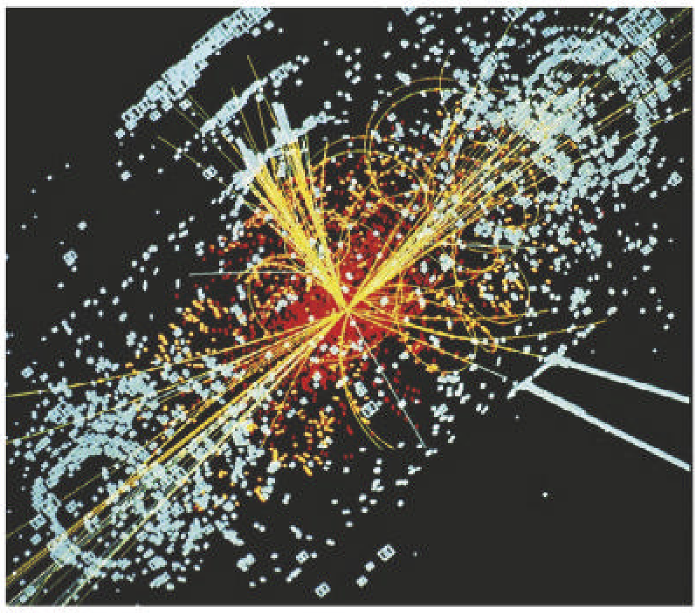
Reported by Robert Lea

© Tobias Roetsch

The expansion of the universe is a phenomenon that can only really be measured by observing galaxies separated by massive gulfs of space. The further apart, the faster they race away from each other. And that effect is speeding up. Dark energy is the name given to the hypothetical force that is causing this acceleration. Think of it as gravity's 'evil' counterpart, providing a negative pressure that fills the universe and drives objects apart at an increasingly rapid rate. But dark energy doesn't seem to work on objects as gravity does. Instead it preys on the very fabric of the cosmos itself – expanding the very space between objects.

Despite the fact it accounts for roughly 69 per cent of the universe's total energy, we know very little about this mysterious, repulsive energy. We aren't completely in the dark about dark energy's 'secret identity', however. Cosmologists are aware of a number of 'prime suspects' that could account for its effects. "The leading candidate is the cosmological constant, or lambda, which we associate with the vacuum space's energy," Luz Ángela García, a physicist at Universidad ECCI, Bogotá, Colombia, explains. "Other possible candidates are quintessence fields, proposed in the early 21st century to establish a 'fifth force' responsible for the negative pressure that might cause the accelerated expansion of the universe."

García, whose work involves finding alternative models to describe dark energy, as well as testing characteristics of this mysterious force, continues: "From this fifth force, many flavours of these fields have appeared in the literature, like K-essence, tachyonic fields, phantom fields and galileons, among many others." With so many potential candidates for dark energy, it's reasonable to ask if dark energy might arise from more than one source. Yet this is a question that cosmologists are only really beginning to consider. "There is no direct evidence for dark energy emerging from more than one source," García posits. "But there is no reason to discharge such a possibility either."


©CERN

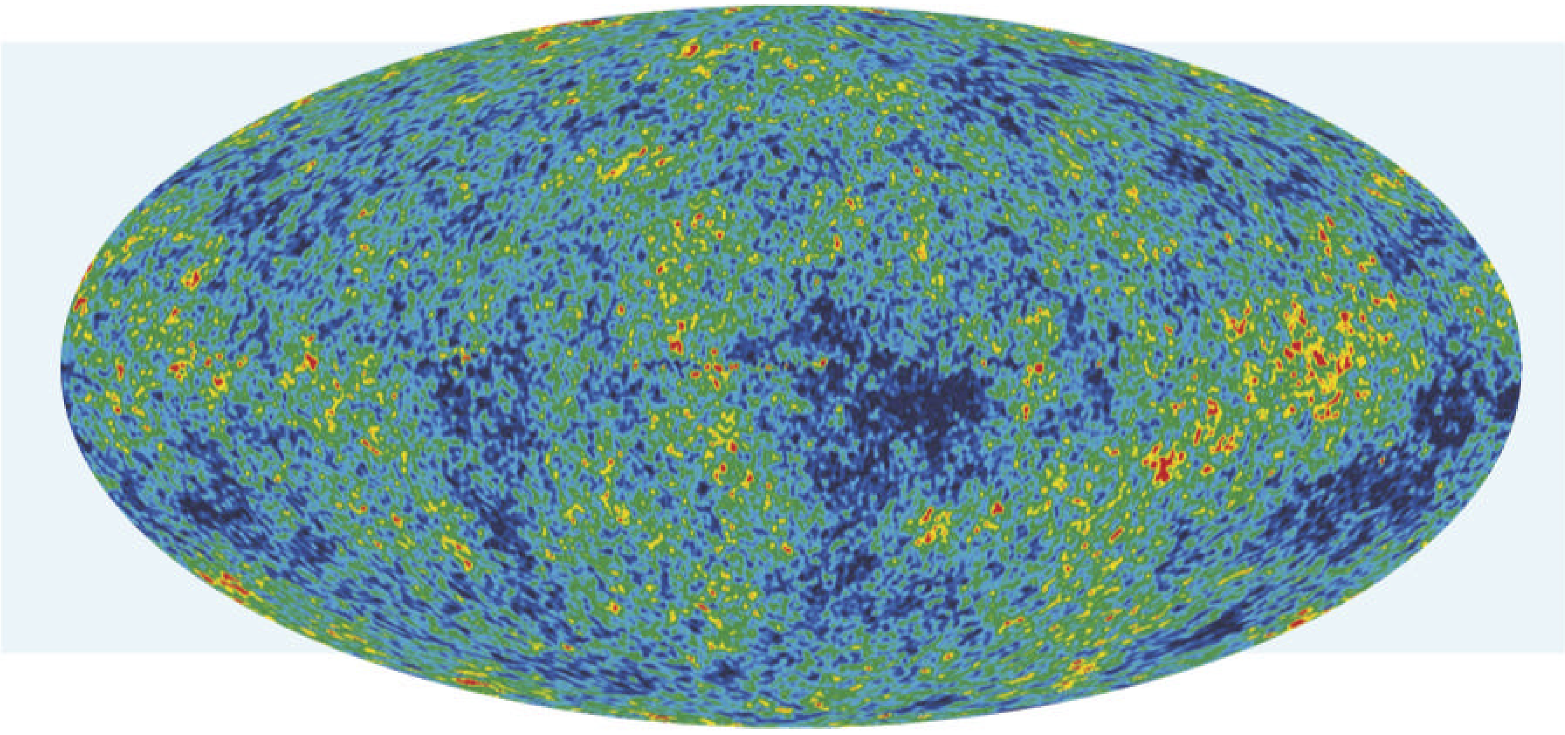
Part of why scientists may have only just begun to consider a multi-source approach to dark energy could be the fact that ever since it was observed, the expansion of the universe has continued to catch researchers off guard. The discovery in the early 20th century by Edwin Hubble that the universe is expanding came as a shock to the scientific community at large, but really caught Albert Einstein flat-footed. Mainly because he'd already accidentally predicted and dismissed it.

When Einstein had first applied his theory of general relativity to cosmological models, the result was a contracting or expanding universe. The problem for Einstein was that he agreed with the scientific consensus at the time of a static universe. To combat this, Einstein introduced the 'cosmological constant' – represented by the Greek letter lambda – to balance the effect of gravity and

Above: The Higgs boson should make a far greater contribution to the cosmological constant than measured

Below: The CMB, leftover radiation from an event in the early universe, confirms the accelerating expansion

> "THERE IS NO DIRECT EVIDENCE FOR DARK ENERGY EMERGING FROM MORE THAN ONE SOURCE" LUZ ÁNGELA GARCÍA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THE DIFFERENT KINDS OF DARK ENERGY

THE COSMOLOGICAL CONSTANT AND VACUUM ENERGY

The leading candidate for dark energy represents vacuum energy arising from 'virtual particles' popping in and out of existence in empty space. The main problem with this candidate is the massive difference between its theoretical value and its observed value.

THE UNIVERSAL QUANTUM FIELD

Researchers struggle to unite cosmology with quantum physics. Another candidate for dark energy arises from quantum mechanics. This suggests that a scalar field permeates the entire universe, replicating the acceleration effects of the cosmological constant.

THE FIFTH FORCE OF NATURE

Should a dark-energy universal scalar field exist, it could represent a fifth force of nature, joining its counterpart gravity, electromagnetism and the strong and weak nuclear forces. This quintessence would differ from the cosmological constant by varying in time.

MULTIPLE SCALAR FIELDS

Rather than the universe being permeated with a single quantum field, how about two or three? Dark energy arising from multiple fields could help unite accelerating expansion observations with string theory using a low-energy universe.

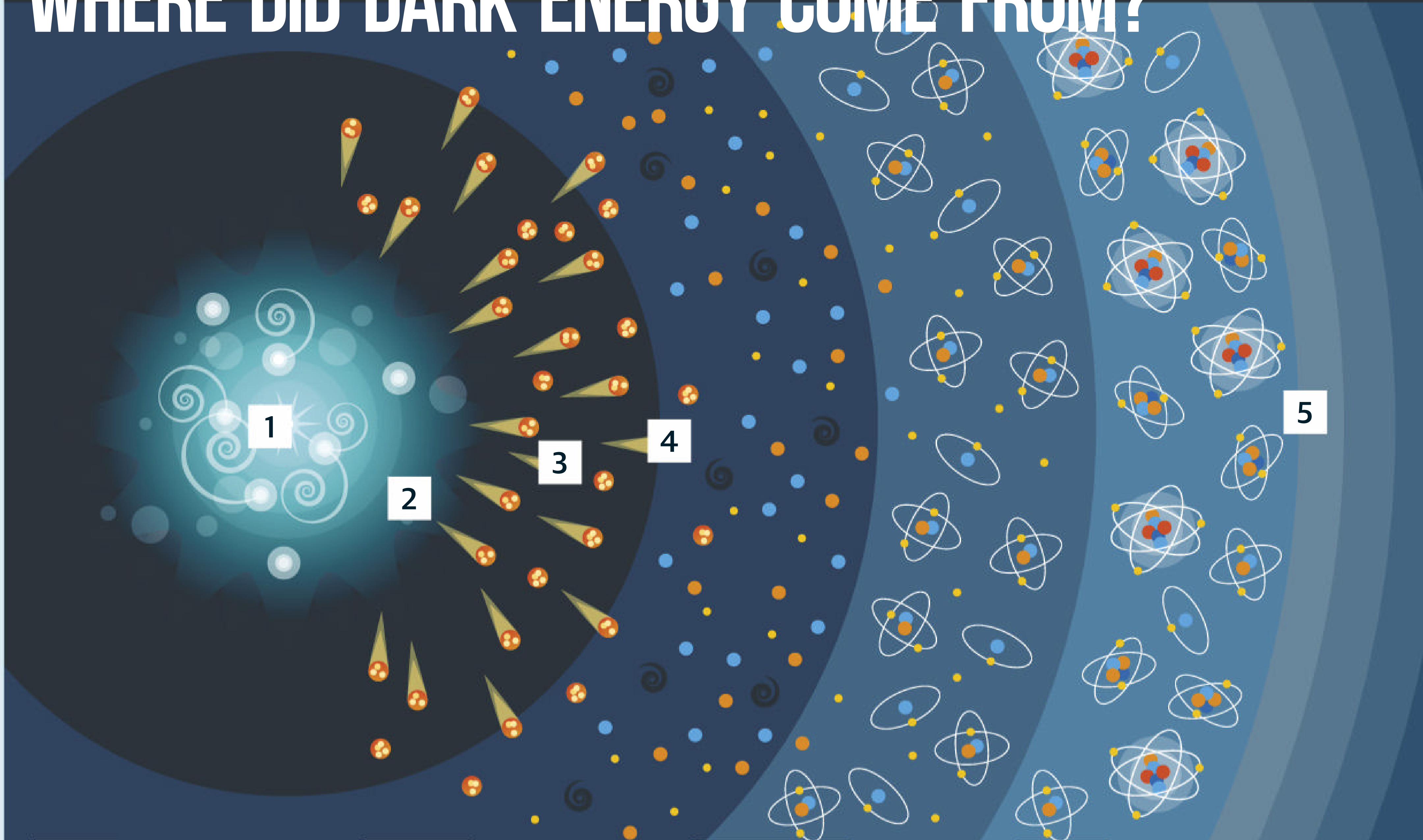
TACHYONIC FIELDS, PHANTOM ENERGY AND MORE

Dark energy is a complete mystery, so theoretical physicists are only limited by their imaginations when suggesting candidates. That has resulted in a raft of plausible candidates such as tachyons – hypothetical particles travelling faster than light and backwards in time.

MODIFIED THEORIES OF GRAVITY

While it's an idea that has fallen out of favour, scientists haven't completely ruled out the idea that the observed effects of dark energy and dark matter are explained by revised theories of gravity, and thus don't exist at all.

WHERE DID DARK ENERGY COME FROM?



0 SECONDS

BEFORE THE BEGINNING

1 All the matter and energy in the universe exists within a single infinitesimal point, a gravitational singularity a billionth the size of a proton. Possibly due to a quantum fluctuation, a period of rapid expansion – 'inflation' – begins.

10^{-43} SECONDS

GRAND UNIFICATION EPOCH

2 The universe is still at an infinitesimal size. At these incredible energy levels, the universe's four fundamental forces are unified. Gravity will soon separate and act independently, followed by electromagnetism.

10^{-32} TO 10^{-12} SECONDS

THE QUARK EPOCH

3 As the universe begins to expand, its 'supercooled' elementary particles form as a 'hot soup' of ionised plasma. Matter particles can interact with the Higgs field, thus acquiring mass. The four fundamental forces are separated.

10 SECONDS

NO MORE POSITRONS

4 Positrons and electrons annihilate each other, with a small imbalance favouring electrons. These electrons impede the travelling of photons, meaning that the universe is opaque to light. This leads to a period called the 'Dark Ages'. Radiation dominates.

© NASA

Left: Supernovae such as 1994D helped the High-Z team discover the acceleration of universal expansion

describe a static universe. History's most famous physicist scrapped it when he was convinced the universe was actually expanding, allegedly describing its introduction as his 'biggest blunder'.

Before that same century drew to a close, however, the expansion of the universe would deliver another shock to science. "In the late years of the past century, two cosmology groups determined that the expansion of the universe was speeding up, thus increasing the rate at which galaxies recede from the others," García explains. "It was proposed that there should be a form of matter-energy, not detected by our instruments to date, that produces a 'repulsive force' among galaxies at cosmic scales. Since this component is still elusive to our telescopes, it was named dark energy." This discovery has since been confirmed in a multitude of ways, including with observations of the cosmic microwave background (CMB), a radiation source that evenly permeates the entire universe and is the leftovers from an event that occurred shortly after the Big Bang.

This discovery was shocking because if the universe began undergoing the rapid period of expansion that cosmologists call inflation just after the Big Bang, the attractive force of gravity should be slowing that expansion down. The fact that the expansion is speeding up means there must be some force acting against gravity. To explain this acceleration and account for energy arising

UNDERSTAND THE THEORETICAL MODEL OF DARK ENERGY
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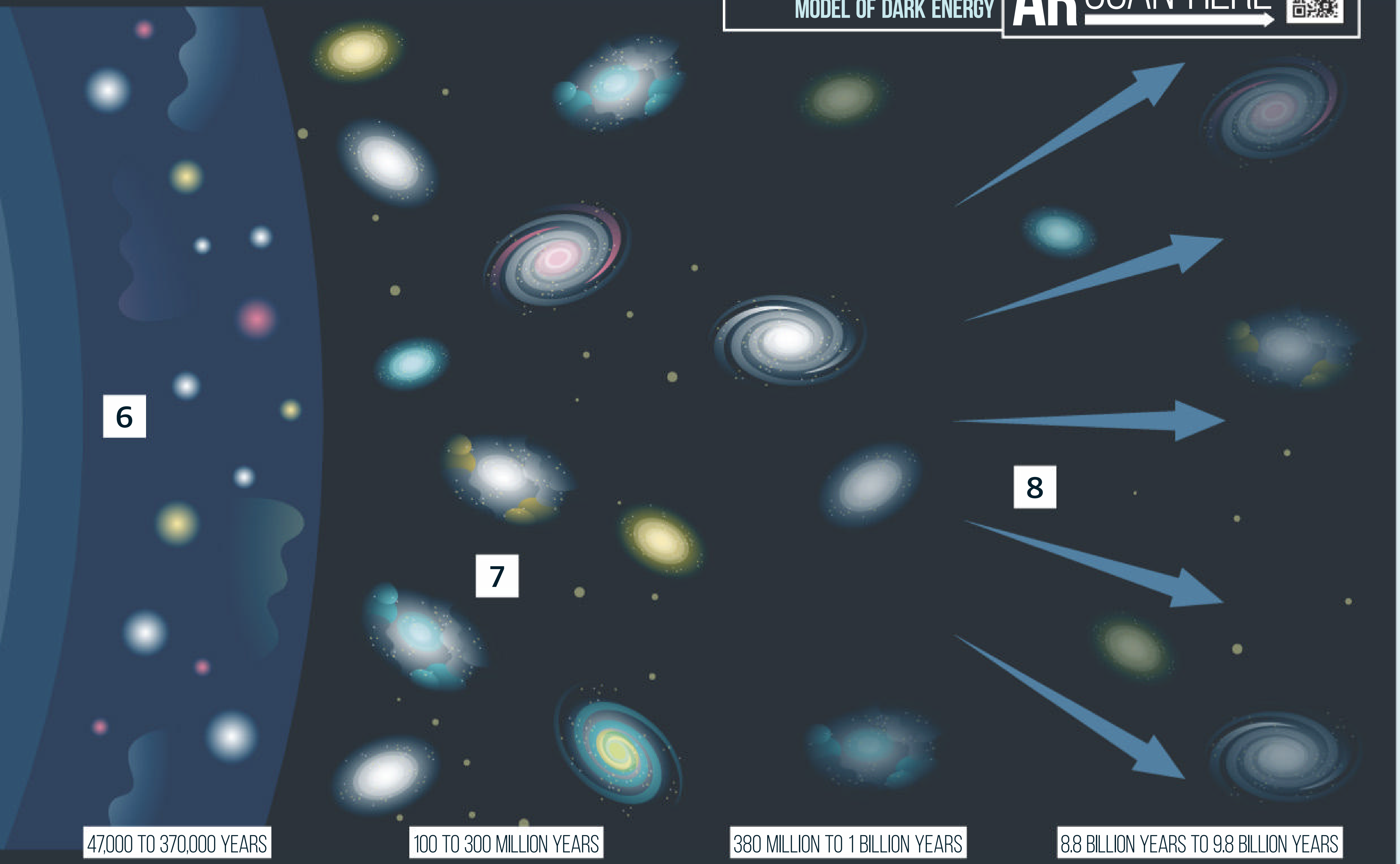

6
7
8
47,000 TO 370,000 YEARS
100 TO 300 MILLION YEARS
380 MILLION TO 1 BILLION YEARS
8.8 BILLION YEARS TO 9.8 BILLION YEARS

THE FIRST LIGHT

5 The gravitational collapse of matter forms structure, and atoms begin to form. As free electrons are snatched up, light is free to travel. The universe becomes transparent. The CMB is left over by the 'last scattering' of photons from electrons.

THE FIRST STARS

6 Ordinary matter particles fall into structures created by dark matter. The stars begin to take shape and the first stars begin to shine. The oldest known star is found at 200 million years. Expansion has slowed considerably.

QUASARS, GALAXIES, BLACK HOLES… OH MY!

7 The first quasars and galaxies are found. The oldest known galaxy with a supermassive black hole exists at 770 million years, hinting that black holes started to grow much earlier than this.

EXPANDING AGAIN: DARK ENERGY DOMINATES

8 Matter loses its dominance over the universe. The dark energy-dominated epoch begins as it accelerates expansion. A new age of expansion begins, but can researchers discover what drives it?

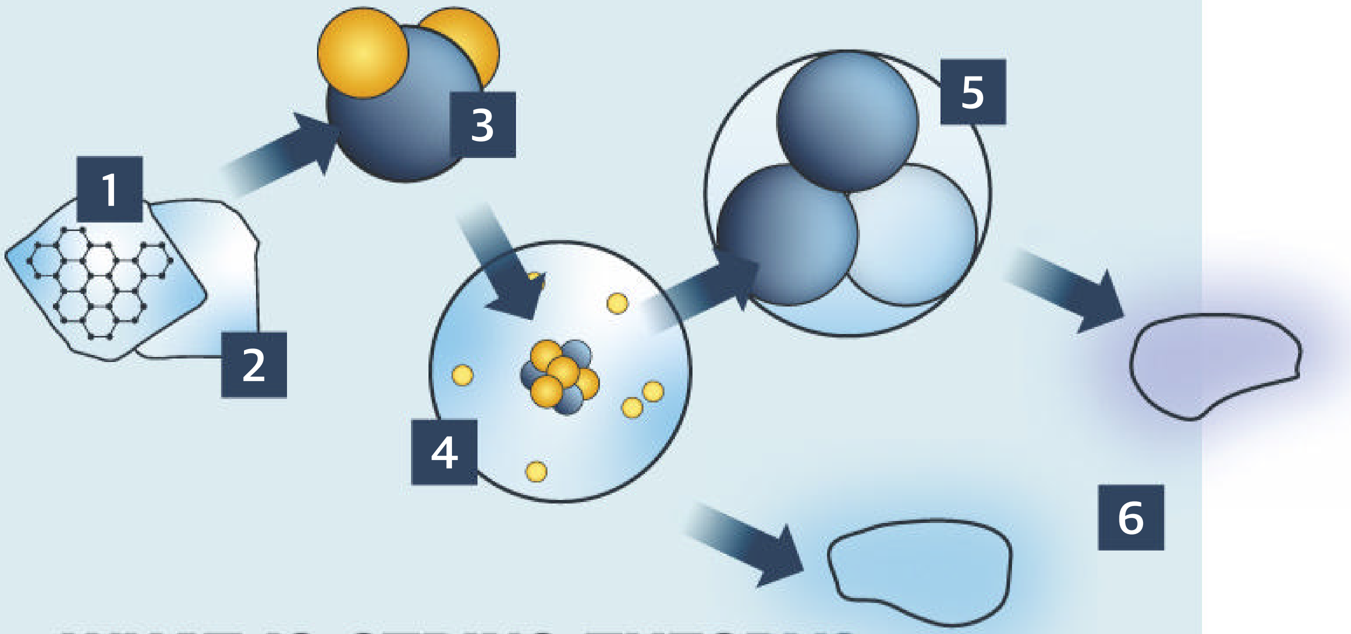
© Getty

from quantum fluctuations in 'empty space' that are inherent to the universe - known as 'vacuum energy' - giving rise to the effects of dark energy, modern cosmologists resurrected the cosmological constant and lambda.

Unfortunately, it still represents a massive headache for cosmologists, with the observed value delivered by astronomy being hundreds of magnitudes smaller than the value predicted by quantum field theory. This has led to the cosmological constant being described as the worst theoretical prediction in the history of science. "The leading explanation for the cosmological constant is the vacuum energy contribution to the expansion of our universe," Lucas Lombriser, a professor at the University of Geneva who has been working on cosmic acceleration models for over a decade, says. "However, we do not understand why this contribution is neither very large nor exactly zero."

Lombriser speculates that the disparity in the value between observations of the cosmological constant and the universe's rate of expansion - and the theoretical figure derived from the contributions of the cosmos' particle content that emerges from quantum field theory - could possibly be rectified by a multi-source approach. "Multiple sources for dark energy would generally allow for more flexibility in the model, which perhaps can explain current tensions that we observe between different cosmological measurements," he suggests, somewhat cautiously. "While a more complicated model with more ingredients allows more flexibility, it also involves more parameters. When selecting between different models as an explanation for our data, we usually opt for the simplest model that can explain the measurements."

García, albeit just as cautiously as Lombriser, puts forward another reason that a 'multi-source' approach to dark energy could help cosmologists understand the cosmological constant: "The main advantage of this approach is that it allows us to explore a larger number of phenomena that could not be explained by a single model," she says. "For instance, an emerging early dark energy (EDE) model could be responsible for cosmic effects still



WHAT IS STRING THEORY?

1 STRING THEORY

String theory expands upon existing theories of matter, adding an extra fundamental level beyond that of fundamental particles.

2 MATTER: THE ICE CUBE

The everyday matter we see around us is made up of molecules. In the example of the ice cube, it consists of molecules of H_2O.

3 MOLECULES: H_2O

These molecules are composed of atoms bonded together. For water, this means one oxygen atom bonding to two hydrogen atoms.

4 ELECTRONS, PROTONS AND NEUTRONS

Within these atoms is an internal structure made up of electrons with a negative charge orbiting a nucleus. This consists of nucleons: protons and neutrons.

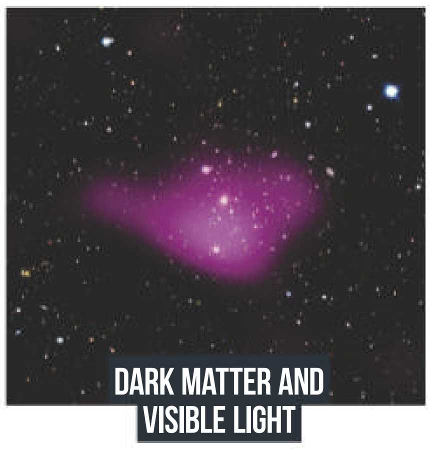
5 NEUTRONS AND PROTONS: QUARKS

The nucleons are made up of 'flavours' of quarks. A neutron contains two down quarks and an up quark, while protons contain two ups and a down.

6 BEYOND QUARKS

If string theory is correct, the fundamental particles – quarks and electrons – are made up of vibrating 'strings' that exist curled up within hidden spatial dimensions.

> "SINCE THIS COMPONENT IS ELUSIVE TO OUR TELESCOPES, IT WAS NAMED DARK ENERGY" LUZ ÁNGELA GARCÍA



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Left: Surveys of galaxies could reveal dark matter clusters that help confirm multi-field dark energy theories

unexplained by the cosmological constant. Then it could decay and deliver its energy density into the latter." García adds that one of the fundamental issues that persists with the cosmological constant in this EDE model is the failure to explain how that energy transfer occurs in the first place. "Exploring a multiple-source approach is relevant to solve these open questions in this theory."

Of course, the cosmological constant is only one dark energy suspect – another is a quantum field that permeates the entirety of space and evolves over time. Just as is the case with the cosmological constant, considering multiple sources for this contribution could solve a multitude of problems presented by such a model.

Valeri Vardanyan is a cosmologist and theoretical physicist at the Kavli Institute of Physics and Mathematics of the Universe (IMPU) and the author of a recent study that puts forward the idea of multiple scalar fields acting as dark energy. "In our paper, we move away from such simple single-field models and put forward the idea that cosmic acceleration could be driven by the dynamics of multiple fields," he tells **All About Space**.

One of the most interesting properties of the model Vardanyan and his colleagues suggest involves the rotation of these multiple scalar fields – something that isn't possible with a single field. "Due to such a rotational motion, several interesting features emerge," the cosmologist continues. "First of all, even though the scalar fields move fast as they rotate, the energy of such a system almost does not change over time." To imagine this, picture a bead placed in a bowl and how it would move as the bowl is kicked sideways. If the bowl spins fast enough, the bead stays at a constant height within it. It's the same for the rotation of the scalar fields and their energy level.

Ultimately, Vardanyan believes that this behaviour means a multiple-field system which 'looks' just like a cosmological constant, despite having very rapid internal dynamics. This could also potentially protect the idea from future findings. "Imagine a situation in the future in which more precise cosmological observations detect no time variation of dark energy," Vardanyan muses. "This would mean the 'death' of scalar-field dark energy ideas, but not for ideas of multiple fields, with this turning motion."

The motion of multiple fields also helps alleviate technical problems associated with explaining dark energy with the use of quantum fields – particularly the difficulty physicists have had in uniting a single universal quantum field with string theory. "Our approach is 'bottom-up' – we didn't start from a fundamental theory, such as string theory, but rather proposed a model that describes a low-energy universe," he says. "Constructing realistic models of cosmic acceleration in the scope of string theory is considered to be a very hard problem, but multiple scalar fields are ubiquitous in string theory constructions. Our model is inspired by string theory, though not directly related to it."

Despite behaving just like the cosmological constant, Vardanyan points out that this multiple-field system possesses a feature that could allow it to be distinguished from its fellow dark energy candidate by future observations. Doing this requires the study of another element of the mysterious 'dark universe': dark matter. "Detailed calculations show that such a turning behaviour leads to enhanced fluctuations in the dark matter sector, which would additionally lead galaxies in the universe to be more clustered."

While considering multiple sources for the origin of dark energy could clean up some problems with both the cosmological constant and a quantum field explanation, doing so may seem a little arbitrary. Both García and Lombriser point to Occam's razor – a loose scientific rule that suggests explanations should require as few additional mechanisms as possible - as a hindrance to the speculation of multiple dark energy sources.

For Vardanyan, however, the complexity of the natural world provides a convincing argument to at least consider multiple sources for dark energy. "The physics governing our visible world - the Standard Model of particle physics - is very complex, with a multitude of ingredients and interplays between these ingredients. Yet the visible world is only a tiny fraction of the energy budget of the universe," Vardanyan concludes. "It is hard to believe, at least for me, that the universe needs such complexity for describing the visible world, while a simple cosmological constant, or even a slightly more complicated single scalar field, is all there is in the dark energy sector. There should be more complexity out there, and multi-field dark energy is taking us one small step closer to understanding that complexity."

Robert Lea
Space science reporter
Rob is a science writer with a degree in physics and astronomy. He specialises in physics, astronomy, astrophysics and quantum physics.

Right: In 2016, Hubble observations showed the universe was expanding faster than predicted

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AR SCAN HERE

HOW DARK ENERGY BEHAVES

1 THE COSMIC TUG OF WAR

In many ways, dark energy can be considered the 'evil' counterpart of gravity. Gravity's influence draws matter in the galaxy together; dark energy works to push it apart.

2 HOLDING IT TOGETHER

Astronomers calculated that the gravitational influence of visible matter alone wasn't enough to hold galaxies together, even before accounting for dark energy.

3 DARK MATTER BOOSTS GRAVITY

There's an unseen form of matter exerting its influence. Dark matter accounts for about 80 per cent of the matter in the universe.

4 THE DARK UNIVERSE AT WAR

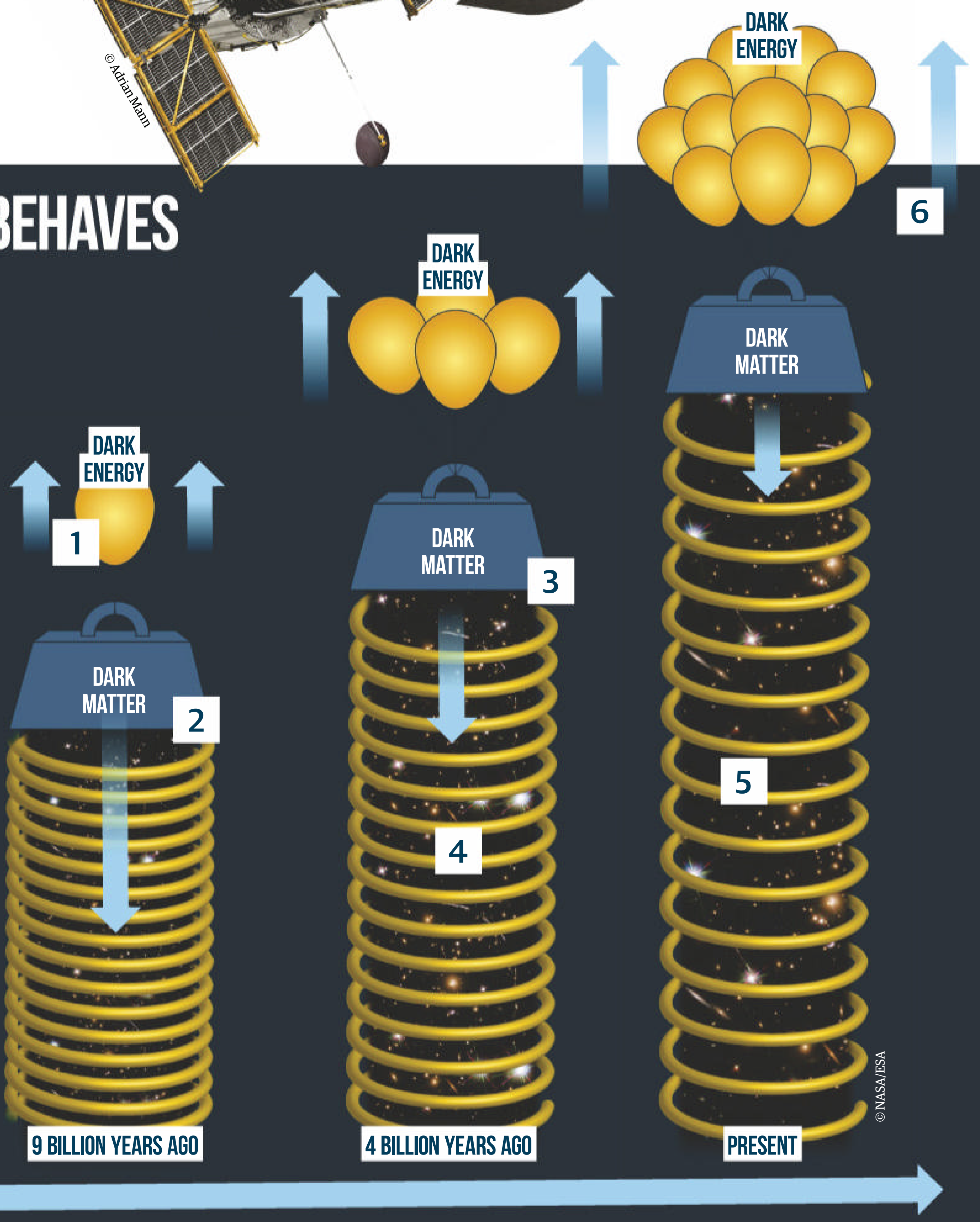
As dark matter outweighs ordinary matter, it's dark matter's gravitational influence that dark energy is working against.

5 THE SPACE BETWEEN US

Dark energy seems to expand the very space between galaxies rather than the galaxies themselves.

6 WHERE WILL IT ALL END?

The universe could succumb to either one of these influences, stretching out to an inevitable 'heat death' or snapping back and contracting in a 'Big Crunch' scenario.



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SUPER-EARTH SEEN ORBITING ONE OF OUR GALAXY'S OLDEST STARS

The new discovery has highlighted that the universe has been birthing rocky worlds for a long time

One of the oldest stars in the Milky Way galaxy hosts an unusually hot, rocky super-Earth planet. Known as TOI-561b, this exoplanet is about 50 per cent larger and three-times more massive than Earth. It whips around its host star in a very close orbit, taking less than 12 hours to complete one lap. Given this close proximity, TOI-561b has an average surface temperature of over 1,726 degrees Celsius (3,140 degrees Fahrenheit), which is too hot to host any form of life as we know it.

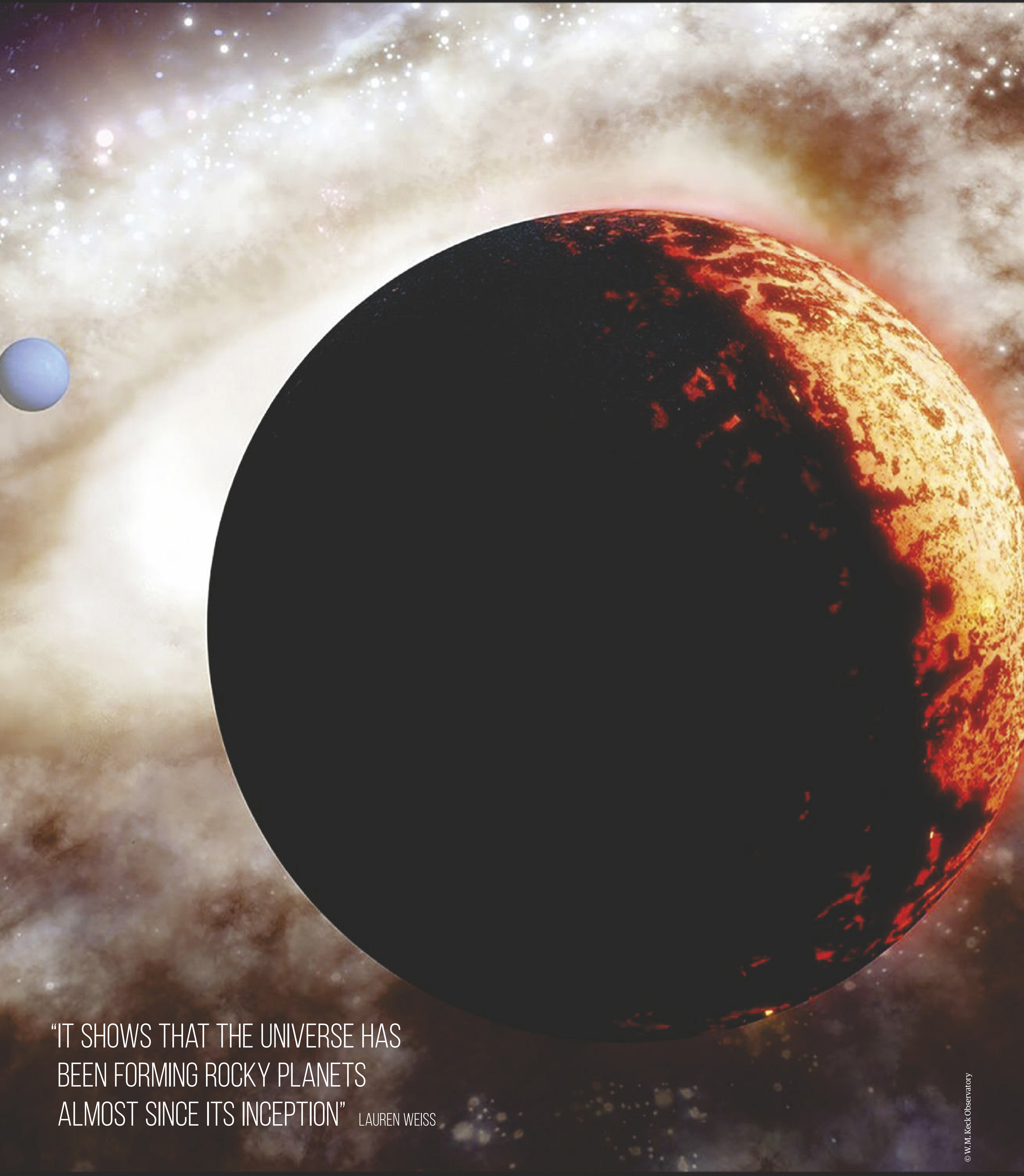
Researchers also found that TOI-561b's density is similar to that of Earth's. "This is surprising, because you'd expect the density to be higher," said Stephen Kane, a planetary astrophysicist from the University of California, Riverside. "This is consistent with the notion that the planet is extremely old."

Heavy elements such as iron and magnesium are manufactured by fusion reactions in the hearts of massive stars. The abundance of these elements has built up over time in the Milky Way and other galaxies as more and more stars churn these materials out and expel them into space when they die in supernova explosions. TOI-561b's low density suggests that it has relatively few heavy elements and is therefore very old, forming perhaps 10 billion or so years ago, Lauren Weiss, a postdoctoral fellow at the University of Hawaii, said. Indeed, the planet's host star, TOI-561, is among a rare population of stars located in a region called the galactic thick disc. These stars are known to have distinctly fewer heavy elements than typical stars in the Milky Way.

"TOI-561b is one of the oldest rocky planets yet discovered," said Weiss. "Its existence shows that the universe has been forming rocky planets almost since its inception 14 billion years ago." Weiss and her colleagues discovered and characterised TOI-561b by studying observations made by NASA's Transiting Exoplanet Survey Satellite (TESS) and the W. M. Keck Observatory in Hawaii. TOI stands for TESS Object of Interest.

The intriguing system lies approximately 280 light years away and harbours two other known planets in addition to TOI-561b. But these two other planets are too big and not dense enough to be rocky, unlike TOI-561b. "Though this particular planet is unlikely to be inhabited today, it may be a harbinger of many rocky worlds yet to be discovered around our galaxy's oldest stars," said Kane.

Right: The rocky world has a tight orbit around its star, where it's heated up to a high temperature



"IT SHOWS THAT THE UNIVERSE HAS BEEN FORMING ROCKY PLANETS ALMOST SINCE ITS INCEPTION" LAUREN WEISS

© W.M. Keck Observatory

MYSTERIES OF THE UNIVERSE

WHAT IS STEVE?

© Krista Trinder; Getty

Photographers who began taking images of unusual lights in the night sky suddenly found themselves to be citizen scientists

Reported by David Crookes

For a long time, photographers have been snapping away at the glowing green dancing lights that are often seen in high-latitude regions of our planet's night sky. Known as aurorae, these light displays attract many thousands of enthusiasts.

But when a growing number of people also began to see a thin purple ribbon of light, interest in this natural celestial phenomenon began to pique even further. Appearing for as little as 20 minutes to as much as an hour, the mysterious purple arcs were reported 30 times across 2015 and 2016, mainly by aurora chasers from Alberta, Canada. And those who had watched the northern lights for many years in this location knew something strange was occurring.

What they were witnessing, they surmised, was a different kind of light show to the ones that they were used to. Unlike a typical aurora which presents itself as an oval of green, blue and red light lasting hours, this phenomenon appeared as a line which extended for hundreds if not thousands of miles. The ribbon of light clearly had a start and end point, and it was often accompanied by an unstable green structure resembling a picket fence-like aurora - a two-for-one light show deal, for want of a better description. "I knew it was rare," says photographer Neil Zeller, who is among many to have witnessed the purple stream, "but at the time it was simply another neat feature of the night sky." Even so, as word spread, photographers began to get together to share more information about what they were seeing.

> "I KNEW IT WAS RARE, BUT AT THE TIME IT WAS SIMPLY ANOTHER NEAT FEATURE OF THE NIGHT SKY"
>
> NEIL ZELLER

Before long, a Facebook group called Alberta Aurora Chasers was set up to encourage people to post their images and experiences of the natural light display. This became a key focal point for the aurora chasers, who enthusiastically pored over the details being shared while marvelling at what had been captured.

For fun, the group's lead administrator, Chris Ratzlaff, named the phenomenon STEVE, in reference to the 2006 animated film *Over the Hedge* in which an unfamiliar shrub is given the same moniker by animals unsure as to what it is. "We also commonly and mistakenly called it a proton arc," Zeller adds. But it soon transpired that aurorae and STEVE were being caused by different physics. It was no standard aurora, that's for sure.

None of those in the group were academic researchers, so for a while the members were a little in the dark about exactly what they were witnessing. Scientists had paid little attention to the phenomenon, but things changed when aurora chasers held a casual meet-up and Zeller showed a photo he had taken of the purple ribbon to Dr Eric Donovan of the University of Calgary. Donovan then called upon Dr Elizabeth MacDonald, a space scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, to take a look. "This was the moment that the science of STEVE began," Zeller says. Indeed, all of a sudden the photographers were on the road to becoming citizen scientists, and their images would prove vital in getting to the bottom of what was going on.

HOW CITIZEN SCIENTISTS HELPED SOLVE THE MYSTERY OF STEVE

AR SCAN HERE

STEVE
BY NUMBERS

25
Width in kilometres

3,000
Temperature of its hot plasma in degrees Celsius

6
Speed of STEVE in kilometres per second

5
Number of countries in which STEVE has been observed

2016
Year STEVE got its name

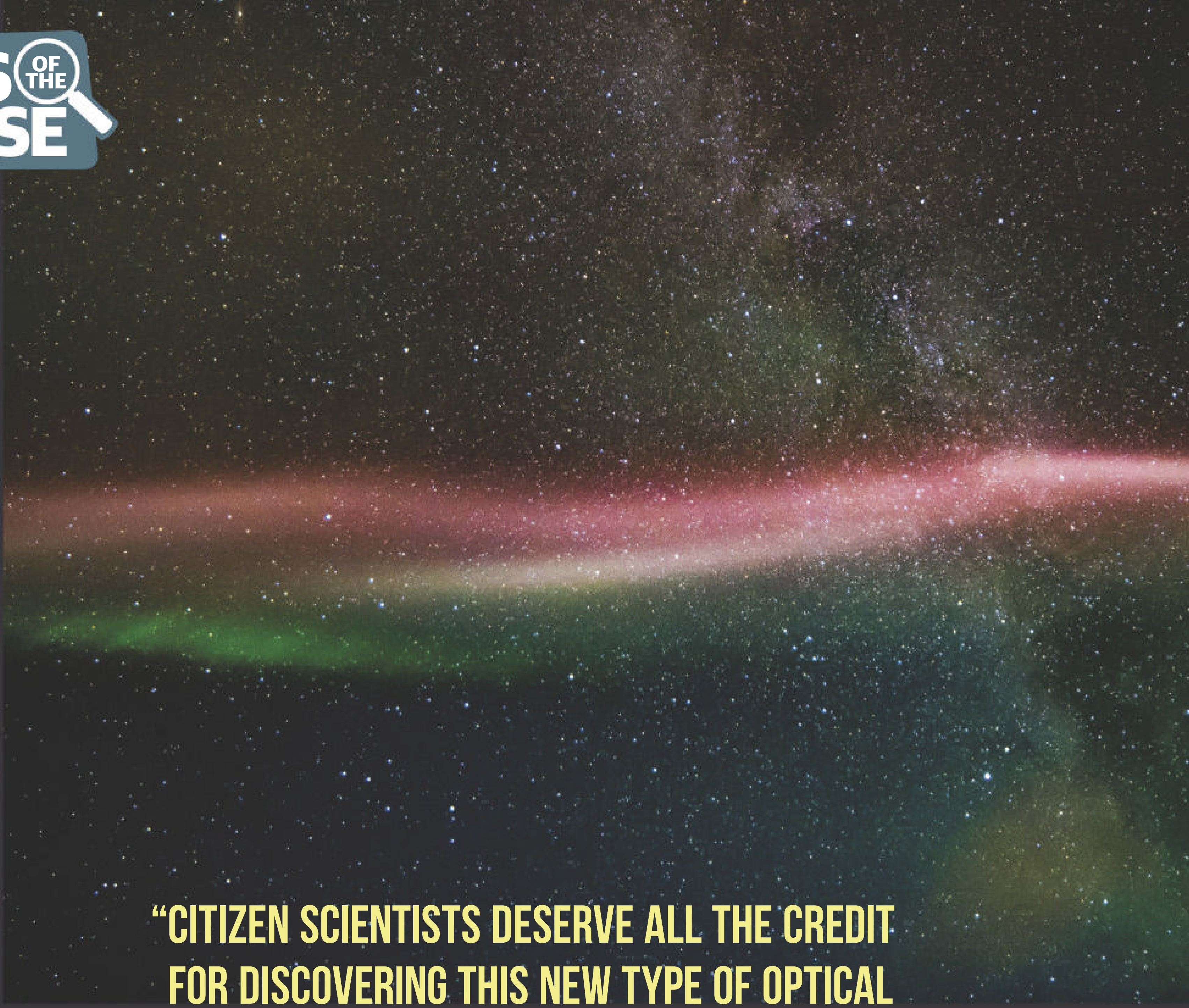
20-60
Number of minutes STEVE has been seen to last

HOURS
Citizen scientists spend hours waiting for STEVE to appear

1,000s
Number of miles to which it can extend

5
Number of years STEVE has been studied

0
Cost to submit your own sightings at aurorasaurus.org



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Above: This stunning shot was taken on 27 September 2017 by Megan Hoffman, with the green light accompanying the length of purple STEVE

> "CITIZEN SCIENTISTS DESERVE ALL THE CREDIT FOR DISCOVERING THIS NEW TYPE OF OPTICAL PHENOMENON WE CALL STEVE" JOSHUA SEMETER

MacDonald was particularly keen to find out more, and to do so she immediately knew that she would benefit from continued contact with the aurora chasers, so attempts were made to forge close relations. Rather than ditching the name STEVE for something a bit less jovial and more academic, it was turned into an acronym meaning Strong Thermal Emission Velocity Enhancement, giving it purpose and the perfect excuse to retain it. MacDonald also made wider use of her citizen science website Aurorasaurus, which is backed with funds from NASA and the National Science Foundation. It encourages aurora chasers to submit reports, sightings and images of STEVE, and it has worked a treat in amassing lots of data.

Crucially, MacDonald's work and the existence of Aurorasaurus has enabled the scientist and her team to draw upon a sizeable and enthusiastic band of citizen scientists who have few quibbles about standing around for hours in the plummeting temperatures of the night in the hope of spotting STEVE. By taking shorter exposure photographs, they've been able to capture the phenomenon perfectly, with sensitive modern cameras and smartphones enabling great strides to be made.

"Citizen scientists deserve all the credit for discovering this new type of optical phenomenon we call STEVE," says Professor Joshua Semeter of Boston University, who is first author on a recent paper shedding further light on STEVE. "In their zeal to capture beautiful images of the natural world, they have serendipitously discovered new fundamental physics, revealing new ways that our atmosphere interacts with the space environment."

In 2018, NASA put out a call for more people to get involved in submitting photographs either on the website or via a mobile app. The space agency said it would enable better tracking of the chemical and physical processes occurring in near-Earth space and explained that it would allow for a greater understanding of space weather close to our planet so that potential interference with communications and satellite signals could be understood. The reaction was such that breakthroughs continue to be made.

That said, scientists still don't fully understand what is causing STEVE. They know it isn't a normal aurora - the hunch is that it isn't an aurora at all - yet STEVE is thought to be driven by the auroral system. Both are the result of charged particles from the Sun interacting with the magnetic field lines of Earth. But STEVE's glow is not due to charged particles raining down into the upper atmosphere of Earth. Instead, STEVE is associated with subauroral ion drift, or SAID, which occurs roughly 60 degrees above the equator and is driven by substorms in the

© ESA

© Megan Hoffman

Left (top): The European Space Agency's Earth observation satellites have helped to amass more data about STEVE

Left (bottom): Citizen scientist Megan Hoffman captured a whisper of purple amid this aurora in May 2017

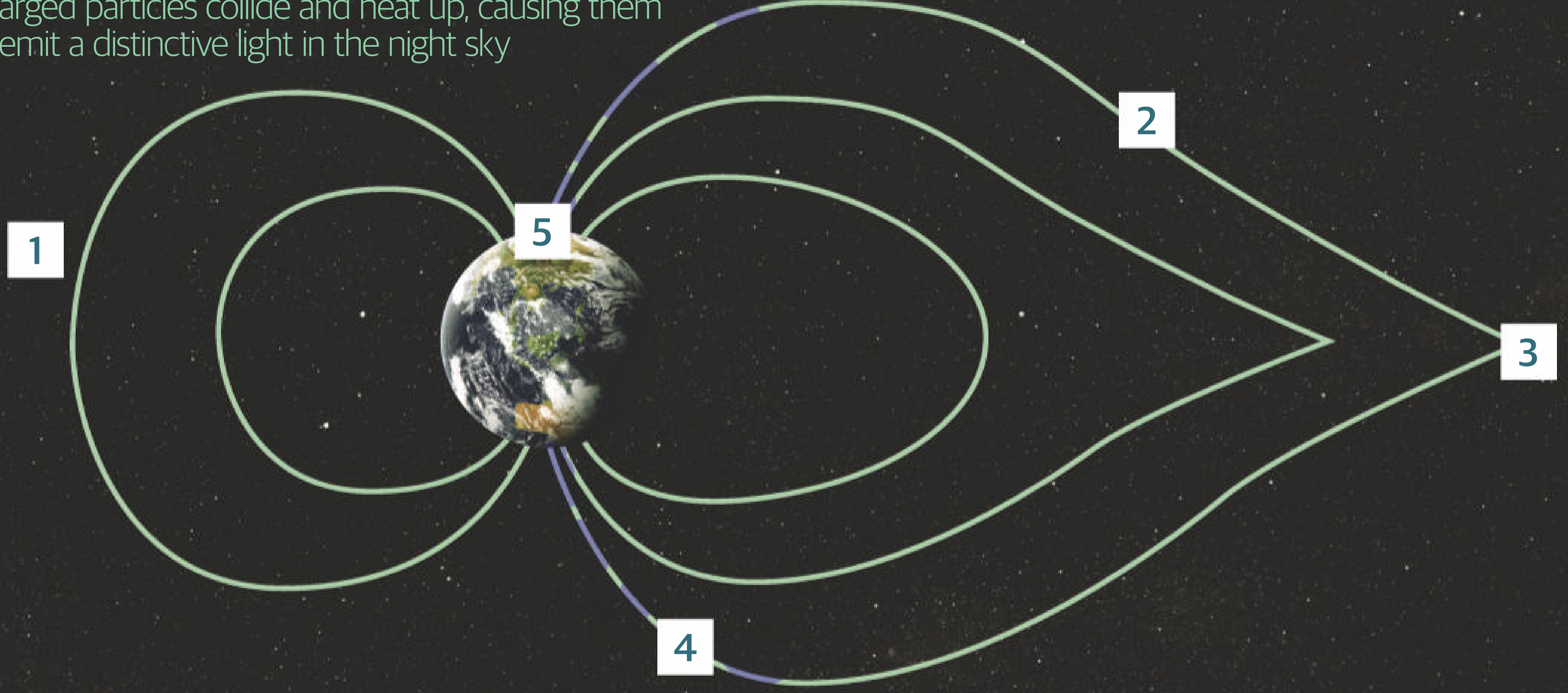
Earth's magnetosphere. Ions move at supersonic speed, flow westward and become heated.

"Aurorae are produced by charged particles streaming along the Earth's magnetic field lines into the atmosphere where they collide with the neutral gases in our outer atmosphere, causing them to glow," Semeter says. "STEVE is produced by charged particles - mostly ions - streaming perpendicular to Earth's magnetic field, in other words, horizontally. When the ion speed reaches a critical value, collisions with the neutral gases cause them to glow. The spectrum of emissions is distinct between these two processes."

Interestingly, STEVE only seems to appear outside of winter, pointing to it being a seasonal phenomenon, and it is linked to space weather such as solar flares and coronal mass ejections. As well as making use of citizen scientists' photographs to get to the bottom of STEVE, researchers have been able to use images from the all-sky cameras run by the University of Calgary and the University of California, Berkeley. Together with the European Space Agency's Swarm satellite, they have captured both the auroral display and STEVE, giving

HOW STEVE'S LIGHT IS LIKELY TO BE GENERATED

Charged particles collide and heat up, causing them to emit a distinctive light in the night sky



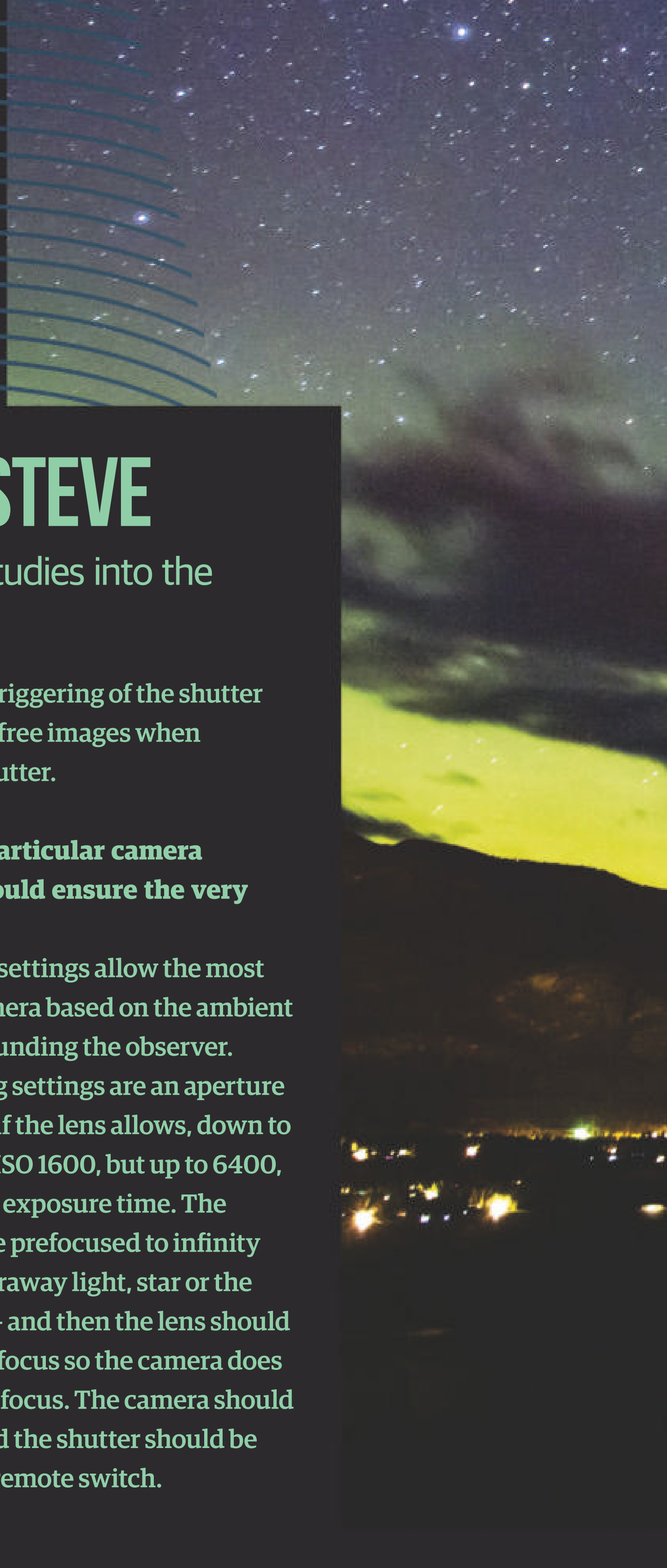
1 Let there be light The Sun sends a flowing river of charged particles called the solar wind towards Earth, applying pressure on our planet's magnetic field.

2 To the dark side The charged particles, or plasma, are sent to the far, night-time side of Earth, where the magnetic field is stretched into the shape of a teardrop with a long tail.

3 A point of friction When the charged particles in the Earth's ionosphere close in, the oppositely directed magnetic field lines collide and reconnect in a process known as magnetic reconnection.

4 Near the equator STEVE's arc aligns east-west, and it is associated with subauroral ion drift, causing the phenomenon to occur about 60 degrees above the equator.

5 Illuminating the sky The resulting friction sends hot jets of charged particles hurtling back towards Earth. When they collide with the upper atmosphere, they are thought to create the light seen in STEVE.



HELP RESEARCHERS DISCOVER MORE ABOUT STEVE

Photographer Neil Zeller became a citizen scientist after his photographs sparked studies into the phenomenon. **All About Space** caught up with him to learn more

Where are some of the best places to capture STEVE?

STEVE tends to be a mid-latitude feature, and the best locations to see STEVE have been between 49 and 51 degrees latitude, but it has occasionally been seen north of 60 degrees latitude. To see the lights, it obviously has to be dark, and to best increase the chances of seeing the lights, the observer should be away from the city lights, with clear skies and a north-facing exposure.

And what's the best time to see the phenomenon?

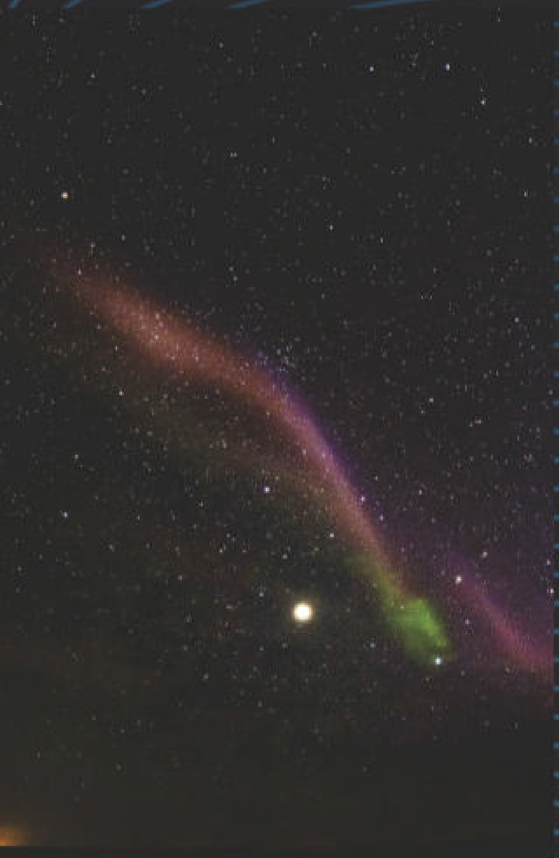
The Sun sends magnetic particles towards the Earth randomly. These particles make up the energy that creates the northern lights. It isn't known how STEVE is related to the northern lights, but when STEVE is visible, it's always on a night that the aurora is present. There are scientists and their instruments monitoring the Sun's emissions and reporting to affected industries - emergency services, power grids, spacecraft operators and more. We as observers and photographers of the lights use this information to predict when we'll see visible aurora. STEVE is usually seen overhead at any latitude, southward of the companion aurora.

What tools do people need to take the best photographs of STEVE?

Taking great photos of the night sky requires a camera that allows the manual setting of the ISO, the aperture and the shutter speed. The camera also needs to allow shutter speeds up to 30 seconds duration, and because we are utilising long-exposure shutter speeds, a tripod or other device to keep the camera perfectly still while shooting is required. A way to trigger the shutter remotely is an asset as well. Remote triggering of the shutter allows for shake-free images when activating the shutter.

Are there any particular camera settings that would ensure the very best images?

The best camera settings allow the most light into the camera based on the ambient conditions surrounding the observer. Common starting settings are an aperture of f/2.8, or wider if the lens allows, down to f/1.4 commonly; ISO 1600, but up to 6400, and a ten-second exposure time. The camera should be prefocused to infinity - focusing on a faraway light, star or the Moon work well - and then the lens should be set to manual focus so the camera does not hunt for auto focus. The camera should be on a tripod and the shutter should be activated with a remote switch.



Left: STEVE mostly emits light in purple hues, rather than the green, blue and red of aurorae

© Megan Hoffman

scientists the benefit of both ground and satellite views, which has allowed for crucial insights.

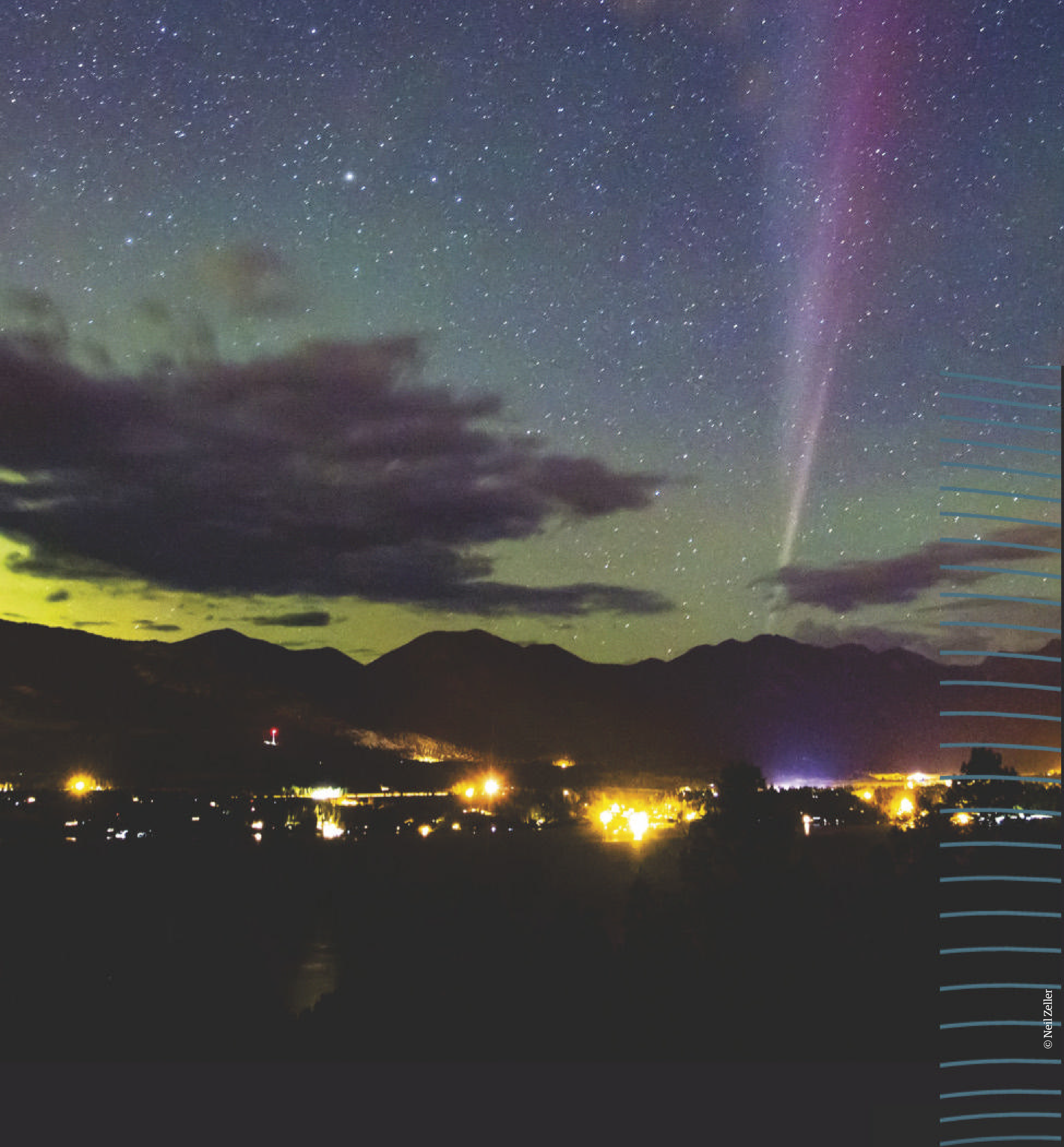
For starters, the all-sky data shows that STEVE appears at lower latitudes to an aurora - the magnetic fields to which the charged particles connect are therefore closer to the Earth's equator. Secondly, the ion drift of STEVE is accompanied by a visual light which had not been known prior to the recent studies. This is the first time an extremely fast and hot SAID event has been linked to the occurrence of an optical emission.

The new findings are encouraging more attention to be paid to research of the subauroral zone, which has long been lacking. Now there's an indication that unknown chemical processes are in play there. "The flowing ions are produced by an electric field imposed on the atmosphere from above, from the Earth's magnetosphere," Semeter adds. "We know that this ion flow produces turbulence from other indirect measurements, and the green optical emissions provide a new optical diagnostic of this turbulence. Having an observable optical signature of this physics provides new constraints, allowing us to study the spatial structure of plasma turbulence induced in our outer atmosphere."

But what of the green vertical picket fence-like streaks that accompany many incidences of STEVE in the altitude range of 100 to 110 kilometres (62 to 67 miles)? Could they be a type of aurora that is simply running alongside the purple ribbon? Again it would appear not.

Researchers have worked on a paper which suggests this aspect of STEVE's light show is different to that of an aurora. To explain, with aurorae the electrons from the magnetosphere make nitrogen glow blue and oxygen glow green, but with the picket fence of STEVE there is no indication of any nitrogen emission.

"If you compare a standard aurora with STEVE, you'll see some similarities; you can readily see the differences in colour and general morphology, for example," Semeter says. "A red-purplish colour is the emission produced by the flowing ions. The green features are thought to be caused by electrons energised by turbulence



© Neil Zeller

in the plasma, produced as a secondary consequence of the ion flow.

Intriguingly, however, there are tiny green streaks jutting out of the bottom of some stripes which would not be the result of an electron shower. "They are at about 100 kilometres (62 miles) altitude, but none of these optical emissions are yet well understood," says Semeter, who indicates this shows that something extra special is happening with STEVE.

But what? By closely looking at the images taken by citizen scientists, the researchers say the horizontal green streaks are not actually lines. They may well be moving points of light that show as a line because of how they blur when captured by a camera as they travel through the atmosphere. But why do they appear in the first place? Semeter says the green features are balls of gas that move slower than the purple emissions, and this could be due to turbulence in the charged particles and magnetic field.

"The narrow green streaks we discovered below the main STEVE arc are thought to be caused by electrons which become heated by plasma turbulence caused by the rapidly flowing ion river," he explains. The light nature of these may cause them to become entangled in the magnetic field lines, exciting pockets of oxygen and causing a pure green light to shine bright."

All of this means scientists are getting closer to cracking this particular mystery, but one thing's for sure, studies will continue, in particular to see if electron showers do actually occur in the region of a STEVE picket fence.

"Our paper is the tip of the iceberg in this new area of these tiny little pieces of the picket fence," says MacDonald. "Something we do in physics is try to chip away to increase our understanding, and the paper establishes the altitude range and some of the techniques we can use to identify these features. Then they can be better resolved in other observations."

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

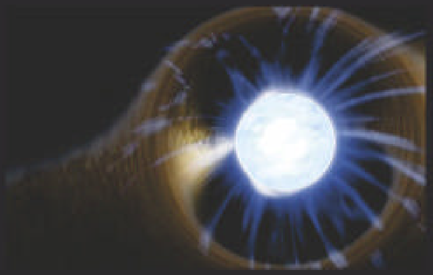
Above: Neil Zeller did not plan to become a citizen scientist, and took photos like this simply for the beauty of STEVE

THE THEORIES

What could be causing these beautiful light shows above Earth?

1 It's an aurora

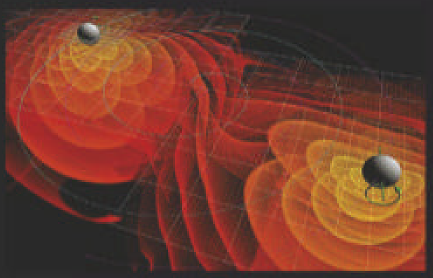
If it is an aurora – and the general consensus is that it is not, even though it is made of light and driven by the auroral system according to MacDonald – then it's certainly far from being a normal one.



© NASA

2 It has moving points of light

Small green streaks within STEVE may be due to moving points of light. These could appear elongated when photographed because the camera is causing them to blur, but some images don't seem to confirm this.



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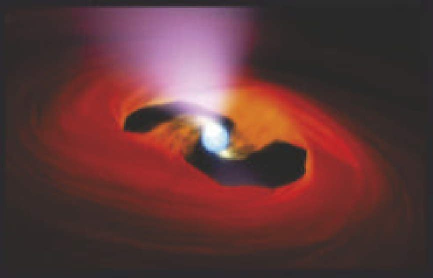
3 Turbulence is to blame

The purple emissions could be due to ions moving at supersonic speeds. The green emissions may be present simply because of slower moving structures. Turbulence in space particles has already been observed in the ionospheric plasma.



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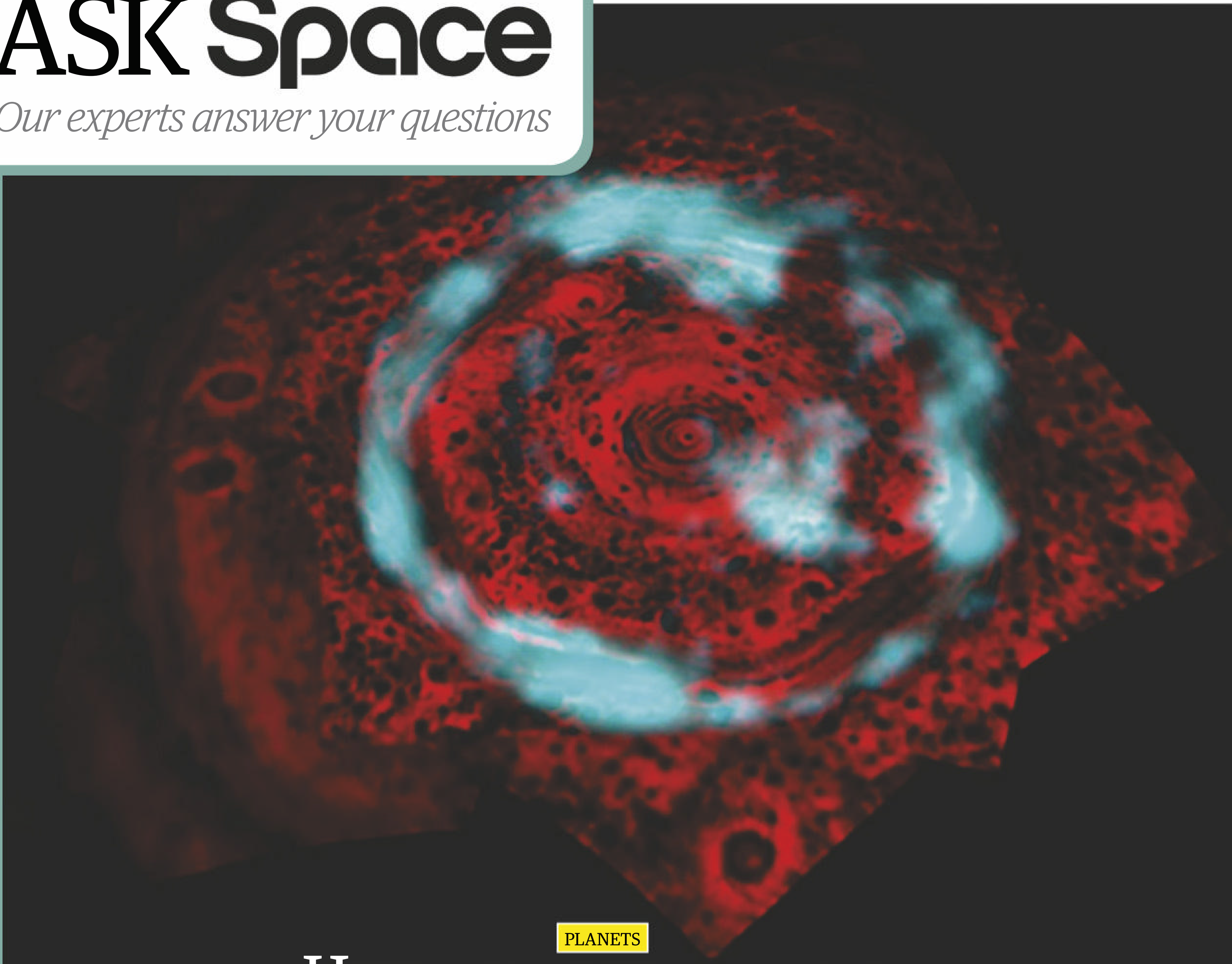

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PLANETS

Have we seen aurorae on other worlds?

Anyone who has ever witnessed an aurora will know just how magnificent this natural phenomenon is. Sometimes forming a diffuse green glow on the poleward horizon, or if conditions are just right a spectacular overhead explosion of colour in the night sky, the privilege of witnessing an aurora first-hand is something many wish for.

Aurorae are the stunning result of a complex chain of interactions that start at the Sun. Solar particles travel outward from the Sun, in what is known as the solar wind, and interact with Earth's magnetic field. While most of the solar wind is deflected by this magnetic barrier, under certain conditions, some of it can break through. These charged particles are then funnelled from inside our magnetic field down into our atmosphere, near the poles. As the charged particles interact with our atmospheric gases, they transfer energy to those gases, causing them to emit light of different colours.

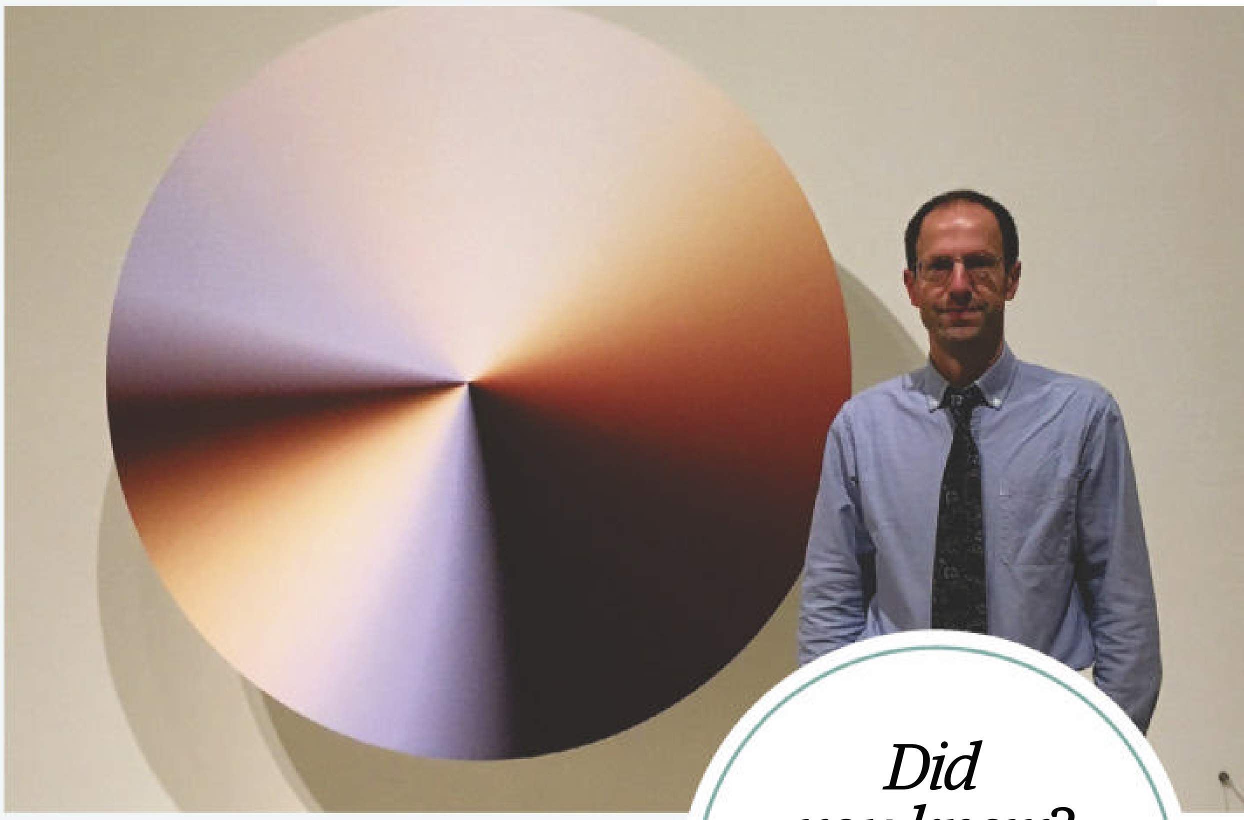
But Earth isn't unique in having aurorae. Other planets do too. In fact, any planet with a magnetic field and atmosphere will have its own aurorae. Thanks to spacecraft such as Cassini and the Hubble Space Telescope, we've been able to identify aurorae on many of the planets in our Solar System. The exact nature of these aurorae, such as their colour and size, is different from Earth's, since their atmospheres and magnetospheres are different too.

Nathan Case is a senior research associate in space and planetary physics at Lancaster University

Above: An aurora over the northern polar region of Saturn as seen in different wavelengths of light by NASA's Cassini spacecraft

COSMOLOGY

How do we know that the universe is a 'cosmic latte' colour?



© Ivan Baldry

When we go outside and look at the night sky, it looks black in between the stars. But that is because we cannot see the millions of faint galaxies that are spread throughout the universe; our eyes cannot detect enough of this light. Instead we can use a telescope and analyse the light from millions of galaxies, spreading out each galaxy's light into a spectrum, like a rainbow. If we then average the light from these galaxies, we can create a digital spectrum that represents the light emitted in our universe. Comparing this cosmic spectrum with the spectrum of a white light, the universe's colour is beige, or as one of our readers called it, cosmic latte.

This idea was taken further by Katie Paterson's studio in the UK. For their art project, I calculated the colour of the universe over time from the Big Bang and even estimated what it would be like in the far future. From this, the art studio created the colour wheel called the 'Cosmic Spectrum'. The universe started out extremely hot with a blue colour, cooling to orange as the universe expanded. And then the first stars formed in young galaxies, becoming blue again. Now it is the beige-yellow colour, and in the far, far future, trillions of years from now, it will be red again as most of the light could be from red dwarf stars.

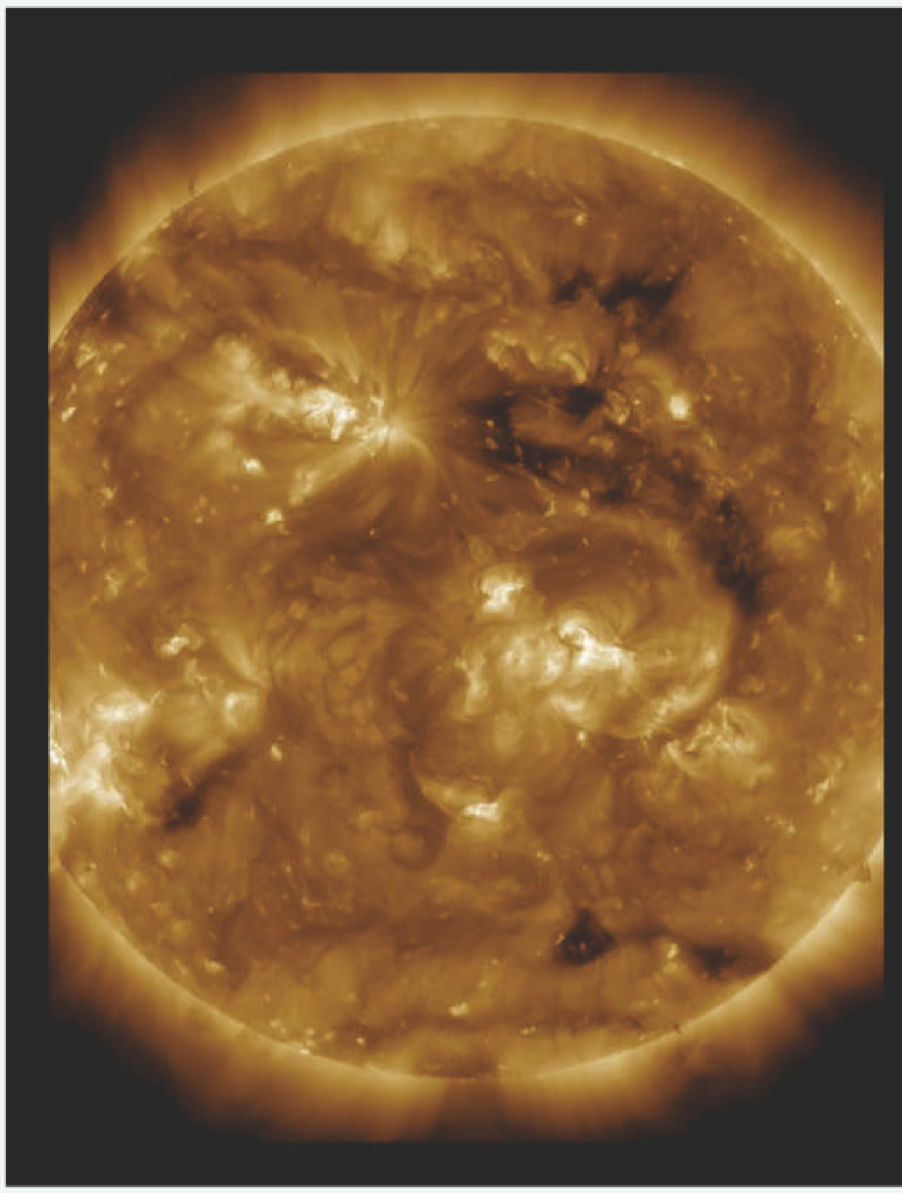
Ivan Baldry is a professor at the Astrophysics Research Institute at Liverpool John Moores University

Did you know?

A team of astronomers from Johns Hopkins University determined the universe was a beige-white in 2002

STARS

Why is light from the Sun white, yet it looks yellow?



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Right: The Sun appears to be a flaming yellow ball when viewed from Earth

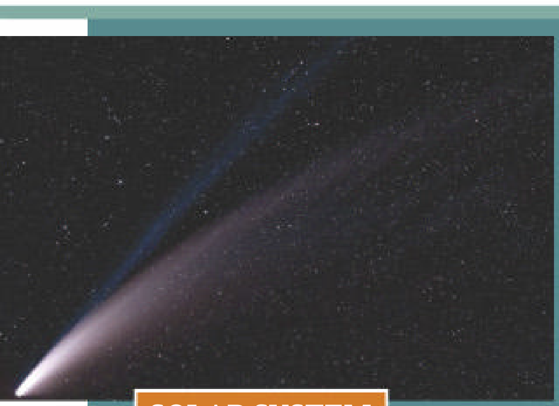
The Earth's atmosphere protects us from the harsh environment of space, but it also alters the way we see objects beyond it. Atoms, molecules and other particles in the air absorb, scatter and refract any light passing through. When we look at the Sun on Earth, the shorter, bluer wavelengths of light are scattered by the atmosphere, only allowing the longer, redder wavelengths through, making it appear yellower. This is more pronounced the more atmosphere the light has to pass through, hence why the Sun is a deep orange-red at sunrise and sunset.

Even when viewed from space, however, light from the Sun isn't perfectly white. Rather than emitting an even amount of light across all colours, the Sun radiates different amounts of light at different wavelengths in a way that is characteristic of its temperature. The Sun shines brightest at green wavelengths, but has more light at the redder side of the visible spectrum than the blue. Recent simulations of stellar light and its perception by the human eye showed that if we were to view the Sun from space - dialling down the brightness so we wouldn't be blinded - it would have a very pale orange tone.

Belinda Nicholson is a postdoctoral research assistant at the University of Oxford Department of Physics

ASK Space

Our experts answer your questions



Source: Wikipedia Commons © SimgDe

SOLAR SYSTEM

What causes a comet to have two tails?

Comets are small chunks of ices and rock floating through our Solar System. Sometimes a comet manages to orbit closer to the Sun, and the heat starts to warm the ice and rock on its surface. Eventually, with enough heat, the ice will become a gas. But comets are small, and their gravity is not enough to keep the gas on the surface. Instead, it expands into the vacuum of space. Similar to a volcano on Earth, this eruption of gas also drags along tiny bits of the rock that makes up the comet. This forms a dust and gas cloud. In the vacuum of space, the gas is very quickly turned into charged particles by ionisation. This charged cloud is called a plasma.

Now the dust particles and the plasma are carried away from the comet, but their different sizes and weight - dust is much heavier than a single charged molecule - mean they are subject to different acceleration processes. The dust is slowly pushed away from the Sun and comet by solar radiation pressure, which we can observe as the bright white, curved tail. The plasma, being much lighter, is quickly pushed away by the solar wind, a stream of particles that emanate from the Sun. This is the bright-blue, straight tail that we can see with telescopes.

Charlotte Götz is an ESA research fellow working at ESTEC in the Netherlands

Left: Comet NEOWISE exhibits a blue ion tail alongside a white tail of dust

Right: The universe may have more dimensions than we envisioned

Below: Galaxies such as the starburst galaxy PLCK G045.1+61.1 appear as reddish dots

© Getty

COSMOLOGY

Could there be more dimensions to the universe?

Yes. At the moment we only know of four dimensions: the three spacial ones plus time - from the point of view of general relativity, physicists find it convenient to count time as a dimension. Additional dimensions could exist, but they must be 'compact' and very small.

As an analogy, you can take the example of a human hair. It looks very much like a one-dimensional object to us, and a creature living on the hair would be able to move along the length of the hair. But if we put the hair under a microscope, we discover it has a radius too, and that the creature could also move along the circumference of the hair. After some walking, it would arrive back at its starting point, which is what is meant by a 'compact' dimension. From measurements at the Large Hadron Collider (LHC), we know that such extra dimensions must have a radius smaller than approximately 10 to 17 centimetres (3.9 to 6.7 inches).

Simon Knapen is a theorist at CERN in Geneva, Switzerland

© ESA/Hubble & NASA

GALAXIES

Why are some galaxies red in the early universe?

Galaxies in the early universe appear very red in images from the Hubble Space Telescope and other observatories. When an astronomer says something is 'red', they generally mean that we receive more energy from it at longer wavelengths than at shorter wavelengths. This avoids the need to understand how our eyes and brains perceive colours.

In the case of galaxies in the early universe, most of their light is emitted by young, hot and very blue stars. But because of the expansion of the universe, this light is redshifted, arriving at our telescopes at much longer wavelengths. Within those galaxies, interstellar gas and dust absorb much of the blue and ultraviolet light, reradiating it at longer wavelengths. In addition, diffuse clouds of intergalactic gas between us and the distant galaxies preferentially absorb and scatter ultraviolet light.

By the time the light from these distant galaxies reaches our telescopes it is very red. Indeed, some of them are so red that they are entirely invisible to optical telescopes and can only be detected by infrared or radio telescopes.

Henry Ferguson is an astronomer at the Space Telescope Science Institute

PLANETS

Have planets ever been known to collide?

Planetary systems form in the dusty discs around young stars, generally with their planets in safely separated zones. However, once formed the planets move around a lot because of the long series of weak but repetitive gravitational tugs they have on each other.

Sometimes they even get thrown out of their systems entirely, doomed to wander forever in cold interstellar space. Other planets change their orbits dramatically without leaving their systems. In fact, in the first hundred million years, the early Earth was smacked into by a Mars-like planet, leaving us with a more massive planet with a brand-new Moon.

This activity dies down after some tens of millions of years since most of the catastrophic evolutionary paths have been explored. Nonetheless, we still see collisions around other stars between bodies as large as our largest asteroids, apparent to us because the collision pulverises a lot of rock into dust that scatters light from the star and is heated to emit in the infrared. Similar collisions have occurred in the last few million years among our own asteroids, evident from tracing their orbits backwards to a single point in space.

George Rieke is regent professor of astronomy and planetary sciences at the University of Arizona

Did you know?

It takes an average of eight minutes and 20 seconds for sunlight to reach Earth

© NASA

Left: An artist's impression of a collision between two rocky exoplanets in the planetary system BD +20 307

Right: Stellar explosions occur during the final evolutionary stages of a massive star

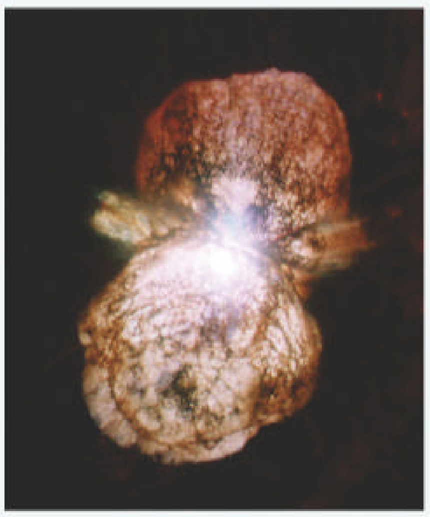
STARS

What causes some stars to explode more than once?

Supernovae bang only once, although novae and X-ray bursts are repetitive. Some stars experience outbursts, but these aren't global, and they are generally not - in a relative sense - energetic. It depends upon the definition of 'explode'. Do they disassemble, or do they merely burp? Supernovae, which I study, come in two general classes: core-collapse explosions of massive stars, and thermonuclear explosions of white dwarfs leading to their likely complete disassembly.

The former leave neutron stars or black holes; the latter nothing. Both produce the elements of existence. The oxygen we breathe comes largely from massive star death. The iron in our haemoglobin comes mostly from the thermonuclear variety. Both are major agents of change in the galaxy, dynamically roiling the medium between the stars while centrally influencing the creation of their next generation. Whatever the outcome and consequences, explosions progressively transform the universe generation after generation, even if each is a singular event.

Adam Burrows is a professor of astrophysical sciences at Princeton University



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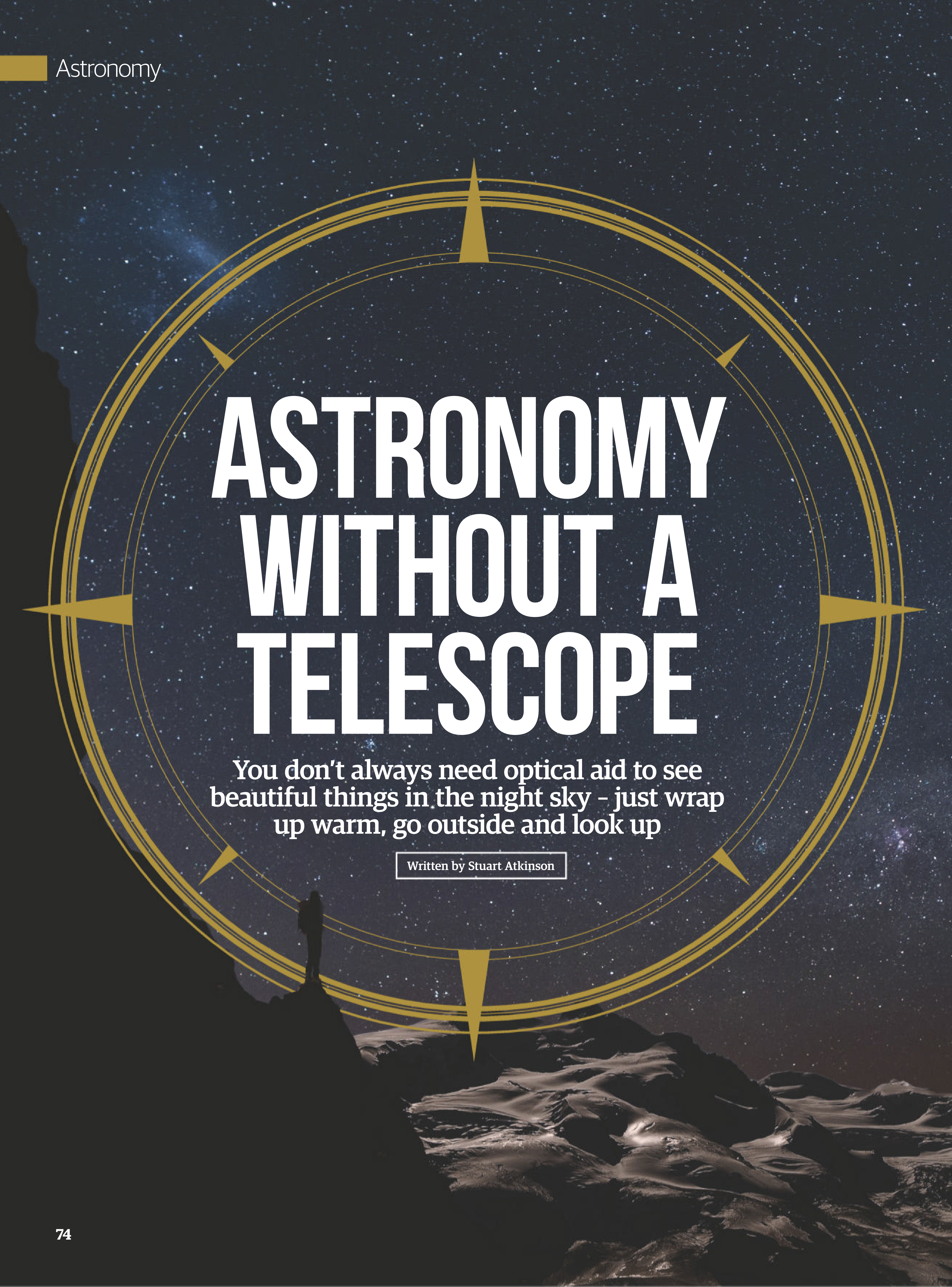


ASTRONOMY WITHOUT A TELESCOPE

You don't always need optical aid to see beautiful things in the night sky – just wrap up warm, go outside and look up

Written by Stuart Atkinson

TOP NAKED-EYE TARGETS

When people hear the term 'astronomer', most automatically picture someone peering into a telescope. But you don't need a telescope to see many amazing and beautiful things in the night sky. You can see many of the wonders of the universe using just your own eyes, or a pair of binoculars.

The telescope has allowed astronomers to see the planets of our Solar System in stunning detail and observe stars, nebulae and galaxies so far away that their dim light has taken millions or even billions of years to reach us. Telescopes make such faint objects look bigger and brighter, but they are totally useless for observing the big things beginners start out looking for - the shapes, or constellations, the brightest stars make in the night sky.

Once a beginner has learned the names and positions of the brightest stars and the constellations they form like giant join-the-dot puzzles, then they can move on to a telescope, zooming in on thrilling sights such as the rings of Saturn, Jupiter's moons and the ice caps of Mars, as well as countless glittering star clusters, misty nebulae and frost-swirl galaxies, but before that there is a wealth of wonderful things to see with just your naked eye, from your own garden.

There are many advantages to naked-eye astronomy over using a telescope. Telescopes are expensive, take time to set up and align and can be very complicated to operate. Naked-eye astronomy is absolutely free, you can do it as soon as you step out your front door and your eyes are very simple to operate - you use them every day!

> "YOU CAN SEE MANY OF THE WONDERS OF THE UNIVERSE USING JUST YOUR OWN EYES, OR A PAIR OF BINOCULARS"

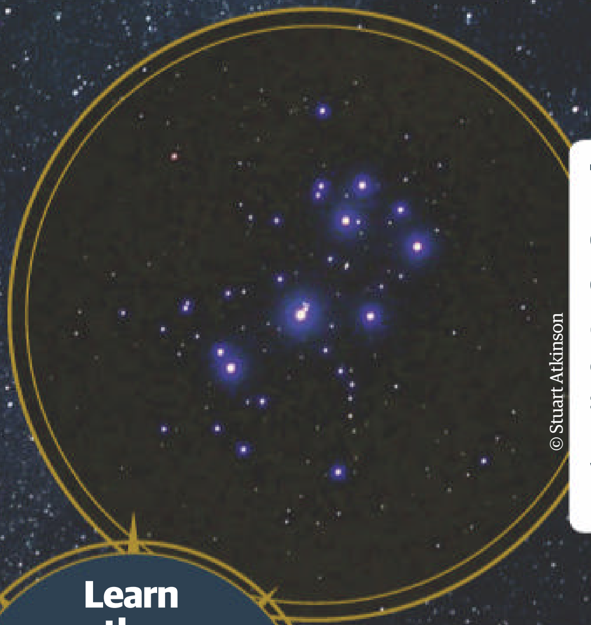
The first things you'll see in the sky on a clear night - unless the Moon is on view, of course - are the stars, and astronomy is essentially the study of stars: how they are born, live and die and the groups and structures they make. Even after all these years, many people don't know what stars actually are. Some still think they are bright objects whirling around the Earth. In fact, stars are balls of very hot gas, almost unimaginably

© Stuart Atkinson

THE MILKY WAY

Observable: All year round, but best seen in summer and autumn

Late on a clear summer night, the sky is cut in half by a misty river of light. This is the famous Milky Way, a band of so many millions of stars that they appear to merge into one long, mottled trail. It looks at its best in summer and early autumn, when its brightest parts are highest in the sky.



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THE PLEIADES (MESSIER 45)

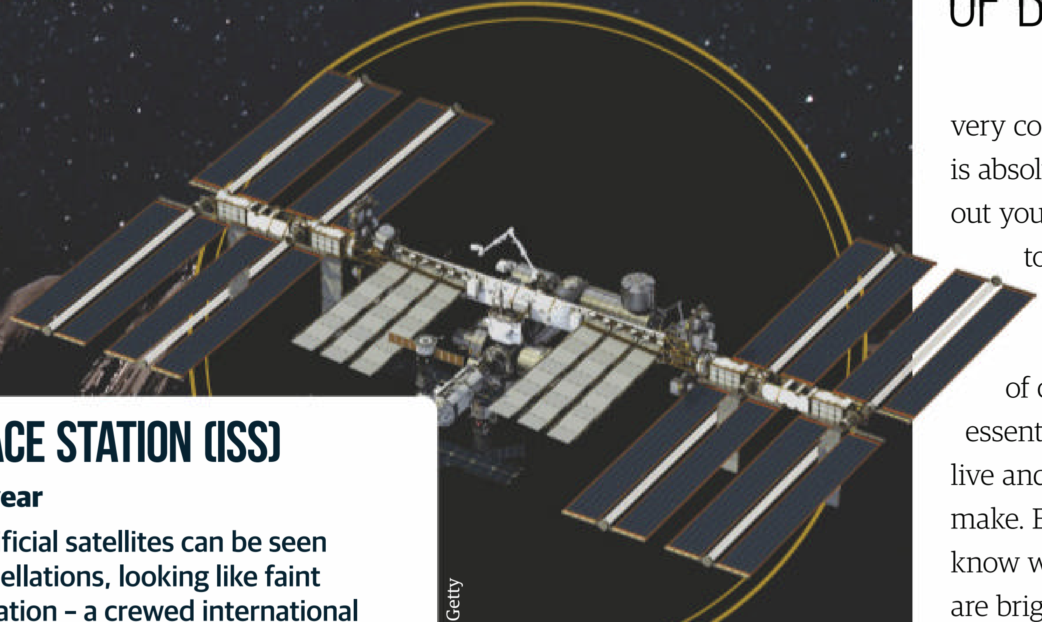
Constellation: Taurus

Observable: Best seen in winter

On frosty winter nights this small, knotty cluster of icy-blue stars looks like a mini Big Dipper shimmering to the upper right of Orion. Its nickname is the 'Seven Sisters' because people with good eyesight can see its seven brightest members with their naked eye.

Learn the constellations

You can use smartphone and tablet planetarium apps to help you to identify the constellations.



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THE INTERNATIONAL SPACE STATION (ISS)

Observable: Throughout the year

On any clear night, countless artificial satellites can be seen drifting slowly through the constellations, looking like faint stars. The International Space Station - a crewed international laboratory orbiting high above the Earth - is much brighter, and can sometimes shine almost as brightly as Venus as it arcs gracefully across the sky from west to east.

© Getty

Dress properly for observing

Make sure you wear warm clothes – including gloves and a hat – when stargazing on cold nights.

© Stuart Atkinson

ORION NEBULA (MESSIER 42)

Constellation: Orion

Observable: Winter

Hanging down from Orion's famous belt is his sword of three much fainter stars. Under a dark sky the middle 'star' is revealed to be a small hazy patch – a nebula, a huge cloud of glowing gas where stars are being born. It's the best in the whole sky for many observers.

ORION'S BELT

Constellation: Orion

Observable: Winter

This striking diagonal line of three blue-white stars draws the eye to Orion on chilly winter nights. It is one of the most famous asterisms – obvious patterns of stars – visible in the sky, and stargazers use it to guide them to many other fascinating objects.

© NASA

VENUS

Constellation: Various

Observable: Different times of the year

Venus is the brightest planet in the sky, and can sometimes appear bright enough to cast faint shadows. It is known as both the 'Evening Star' and 'Morning Star' because it is only seen low in the twilight after sunset or before sunrise, and never high in the dark sky late at night.

© NASA

MARS

Constellation: Various

Observable: Different times of the year

It might not shine as magnificently as Venus, but Mars is always bright enough to be visible to the naked eye as a star-like object. Although its nickname is the Red Planet, it has more of an orange hue. Every two years it becomes much brighter as it makes a close approach to Earth.

© Stuart Atkinson

ANDROMEDA GALAXY (MESSIER 31)

Constellation: Andromeda

Observable: Autumn

M31 is the most distant object visible to the naked eye. When you see this tiny, oval-shaped, misty patch out of the corner of your eye on a cool autumn evening, you're looking at another galaxy so far away in space that its faint light took more than 2 million years to reach us.

far away out in space, and are so enormous they dwarf our planet.

Not all stars are far away, however – we have one on our cosmic doorstep. The Sun is a star, the closest one to Earth. When you see the Sun shining you're seeing a star, and the stars that appear after our Sun has set are all essentially just different versions of it – some bigger, some smaller, some hotter, some cooler and some much further away. Although their huge distances mean we can only ever see them as pinpoints of light with our naked eyes, if you look up at the stars on a clear night you'll notice two things about them straight away: some are much brighter than others, and they're not all the same colour.

You might think that a star is bright because it is close to us, but it's not as simple as that. In a way, stars are like light bulbs; some are very luminous, while others are much less luminous. If all of the stars were the same distance from us, then the most powerful would indeed appear the brightest. But because they are all different distances away, a bright star might actually be a low-power star that is close to us, and a faint star might actually be a very luminous star that only appears faint because it is so far away. The brightest stars have their own names, while the fainter ones don't.

Although they all appear to be the same white colour at first glance, if you look carefully you'll see there are yellow, red and blue stars. These colours tell us how hot the stars are. Just as a glowing

> "YOU MIGHT THINK THAT A STAR IS BRIGHT BECAUSE IT IS CLOSE TO US, BUT IT'S NOT AS SIMPLE AS THAT"

TOP BINOCULAR TARGETS

© Stuart Atkinson

THE BIG DIPPER

Constellation: Ursa Major

Observable: Throughout the year

Probably the most famous star pattern in the whole sky, the Big Dipper is not actually a constellation – it is a pattern of stars within the constellation Ursa Major (the Great Bear). Much fainter stars branching away from it form the bear's legs and head.

© NASA

ANDROMEDA GALAXY'S DWARFS

Constellation: Andromeda

Observable: Autumn

Through binoculars on a dark, Moon-free night, the full size of this beautiful lens-shaped galaxy, more than 2 million light years away from our own Milky Way galaxy, can be fully appreciated. Under good observing conditions you will even see its two much smaller satellite galaxies glowing close by.

Make sure your eyes are dark adapted

After going outside allow at least half an hour for your eyes to adapt to the darkness.

© Getty

JUPITER

Constellation: Various

Observable: Different times of the year

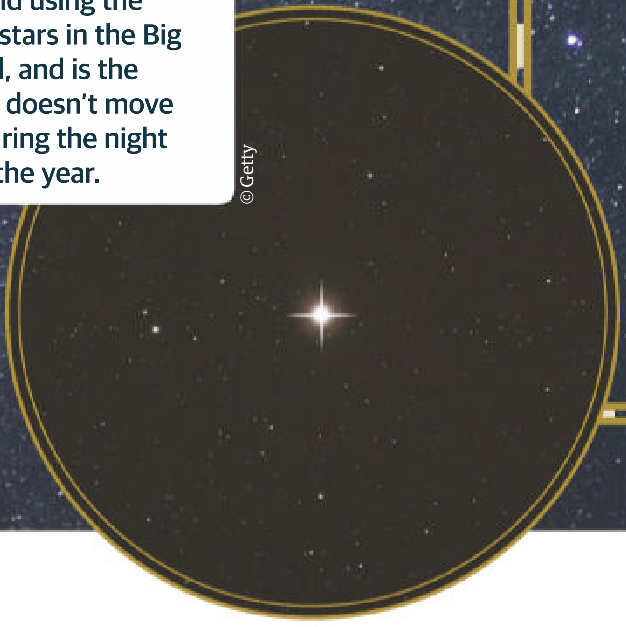
Through even a small pair of binoculars Jupiter will look much brighter than it appears to the naked eye. You will also see some tiny pinpoints of light shining close to it. These are members of its extended family of 79 moons. Sometimes you will see four of them close to Jupiter in a line.

POLARIS, THE POLE STAR

Constellation: Ursa Minor

Observable: Throughout the year

Many people mistakenly think the Pole Star is the brightest star in the whole sky, but it is only the 48th brightest. It's easy to find using the two 'pointer' stars in the Big Dipper's bowl, and is the only star that doesn't move noticeably during the night and through the year.



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ORION NEBULA'S TRAPEZIUM CLUSTER

Constellation: Orion

Observable: Winter

If you hold your binoculars really steady, they'll show you that the 'fuzzy star' in the centre of Orion's Sword is actually a fascinating, misty cloud of blue-grey haze with pinprick stars embedded within it. You'll need a really dark night with no Moon to see it at its best.

Choose the right binoculars

The best binoculars to use for astronomy are 7x35 and 10x50.

red ember rising out of a fire is cooler than a roaring, blue blowtorch flame, red stars are cooler than blue stars. If you could find a thermometer big and strong enough to take the Sun's surface temperature, it would read 6,000 degrees Celsius (10,832 degrees Fahrenheit), fairly typical for a yellow star. Red stars are cooler, with surface temperatures of around 4,000 degrees Celsius (7,232 degrees Fahrenheit), while blue stars are 10,000 degrees Celsius (18,032 degrees Fahrenheit) or higher! You can tell how hot a star in the sky is just by looking for its colour with your naked eye.

Even people who have never looked at the sky in detail know that the stars make patterns called constellations. There are 88 official constellations in the sky, named after animals – real and imaginary – as well as mythical heroes, scientific and musical instruments and other things. Unfortunately only a handful of them look anything like the thing they're meant to be; stargazers need a lot of imagination to see the unicorns, winged horses and sea serpents that live in the night sky!

Although the shapes of the constellations never change, their visibility does. As the Earth turns, the stars are carried across the sky from east to west. Not just the stars, but the Sun too, which is why we have sunrise and sunset, or day and night. The appearance of the night sky changes through the night, with some stars and constellations rising as others set. It also changes through the year

© NASA

BEEHIVE CLUSTER (MESSIER 44)

Constellation: Cancer

Observable: Spring

This ancient star cluster in the centre of the constellation of the Crab is visible to the naked eye as a smudge, but binoculars resolve it into a full Moon-sized collection of dozens of tiny stars. Its nickname comes from its resemblance to a swarm of bees.

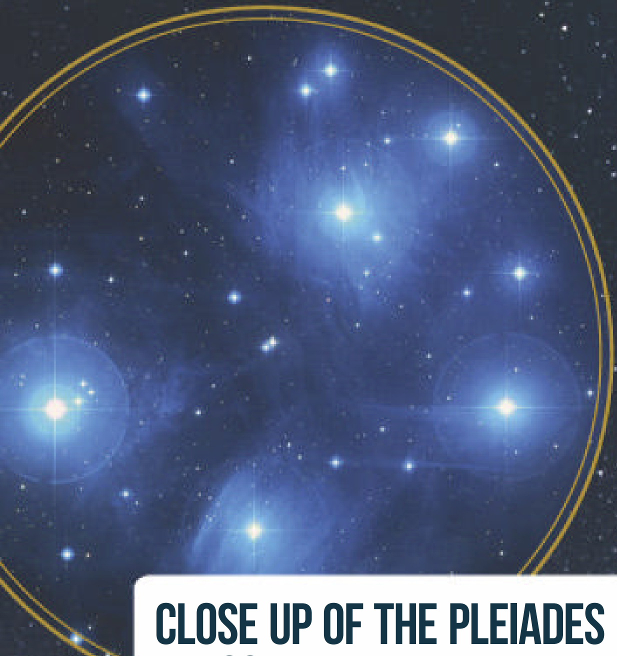
© NASA

CRAB NEBULA (MESSIER 1)

Constellation: Taurus

Observable: Winter

Just off the tip of one of the horns of Taurus, the Bull, is a tiny, pale-grey smudge. This is actually the ghostly remains of a star that blew up thousands of years ago in a cataclysmic explosion called a supernova.



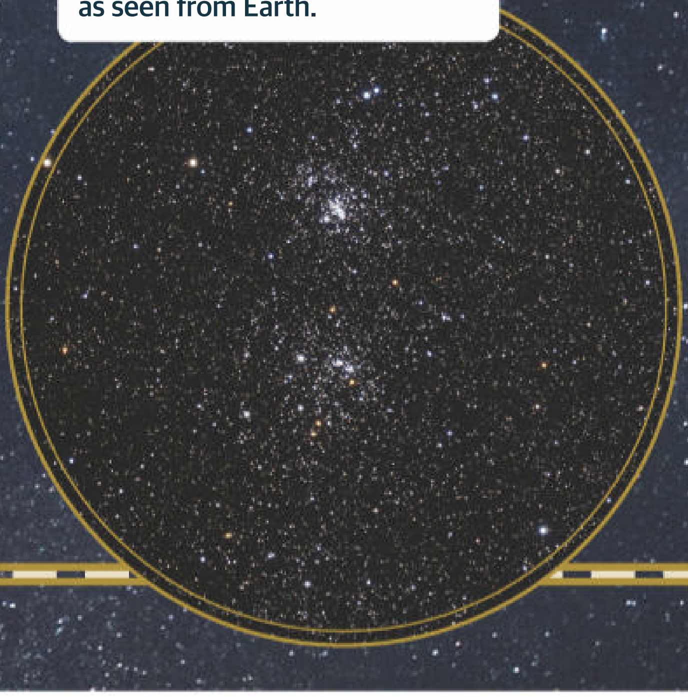
© NASA/ESA

CLOSE UP OF THE PLEIADES (MESSIER 45)

Constellation: Taurus

Observable: Winter

Pretty to the naked eye, this star cluster is a wonderful sight in a pair of binoculars on a bitterly cold winter night. They will show dozens of icy-blue stars crammed up tightly together, making a pattern that looks like a miniature, squashed-up version of the Big Dipper.



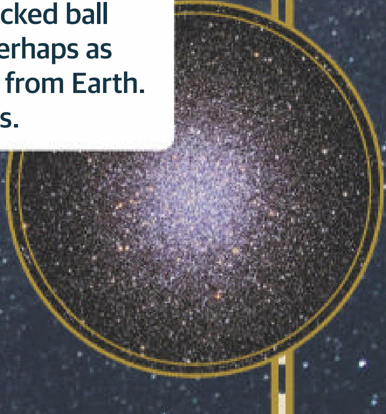
Source: Wikipedia Commons © Genuson

DOUBLE CLUSTER

Constellation: Perseus

Observable: Autumn

In binoculars this intriguing object looks like two piles of salt or sugar close together. In fact, the two star clusters which make up the Double Cluster are not actually related physically. One is much further away than the other. They just happen to lie along the same line of sight as seen from Earth.



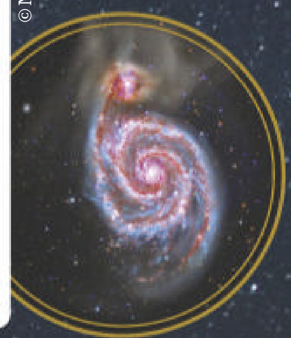
© NASA

GREAT HERCULES CLUSTER (MESSIER 13)

Constellation: Hercules

Observable: Summer

Hanging halfway up in the sky late on summer nights, Messier 13 is a globular cluster, a densely packed ball of many hundreds of thousands of stars – perhaps as many as a million – 23,000 light years away from Earth. It looks like an out-of-focus star in binoculars.



© NASA

WHIRLPOOL GALAXY (MESSIER 51)

Constellation: Canes Venatici

Observable: Spring

This spiral galaxy, found just off the end of the curved handle of the Big Dipper, is more than 30 million light years away and is far too faint to see without binoculars. Even then it only looks like a tiny, round smudge.

too. As the Earth orbits the Sun we look out into different parts of the universe and see different constellations. Each season has its own distinctive sky with its own constellations, although a few are visible all year round.

Only one star stays in the same position all night every night: Polaris, which lies directly above the Earth's northern polar axis. As the Earth turns, the whole sky appears to wheel around the famous 'Pole Star'. But it's not just stars you can see without a telescope. Five of the Solar System's eight planets are visible to the naked eye, looking like stars, but not all at the same time, and sometimes they are too close to the Sun to be seen at all. On a clear night you can also see shooting stars skimming across the sky. These streaks of light aren't actually stars – they're grains of space dust burning up in Earth's atmosphere.

Most nights you can see a meteor every half hour or so just by chance, but around a dozen times each year a predictable 'meteor shower' sends many more zipping across the sky, sometimes dozens or even hundreds every hour for one special night. Most meteors are just bright enough to catch your eye, but occasionally a much brighter 'fireball' crosses the sky, flaring before fading away.

Avoid light pollution

Find somewhere well away from street lamps, security lights and exterior building lighting to have the best possible view of the stars.

© NASA

MESSIER 81 AND MESSIER 82

Constellation: Ursa Major

Observable: Autumn and winter

This very close pair of galaxies both fit easily in the same binocular field of view. The larger and brighter of the two, Messier 81, is a spiral galaxy that appears round, while the smaller and fainter Messier 82 is short and elongated.

SPECIAL

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What's in the sky?

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Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

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2 MAR
Comet C/2020 R4 (ATLAS) reaches perihelion in Aquarius at magnitude +12

2 MAR
Mercury reaches half phase (dichotomy) in the morning sky, shining brightly at +0.1

6 MAR
Mercury reaches greatest elongation west in the morning sky, glowing at +0.1

9 MAR
Conjunction between the Moon and Saturn in Capricornus

Source: Wikipdepia Commons © Stefan2499

10 MAR
Conjunction between the Moon and Jupiter, within 4°02' of each other in Capricornus

19 MAR
Conjunction between the Moon and Mars in Taurus

Source: Wikipedia Commons © Wikihelp7586

20 MAR
March equinox

24 MAR
Comet 10P/Tempel makes its closest approach to the Sun in Aquarius

4 MAR

Asteroid 4 Vesta reaches opposition in Leo, glowing at magnitude +6.2

10 MAR

Close approach of the Moon and Saturn, within 3°35′ of each other in Capricornus

© NASA/JPL

© NASA/JPL

19 MAR

Close approach of the Moon and Mars, passing within 1°51 of each other in Taurus

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

Jargon buster

Conjunction

This is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Greatest elongation

This is when the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as bright evening stars during greatest eastern elongations and as morning stars during western elongations.

Declination (Dec)

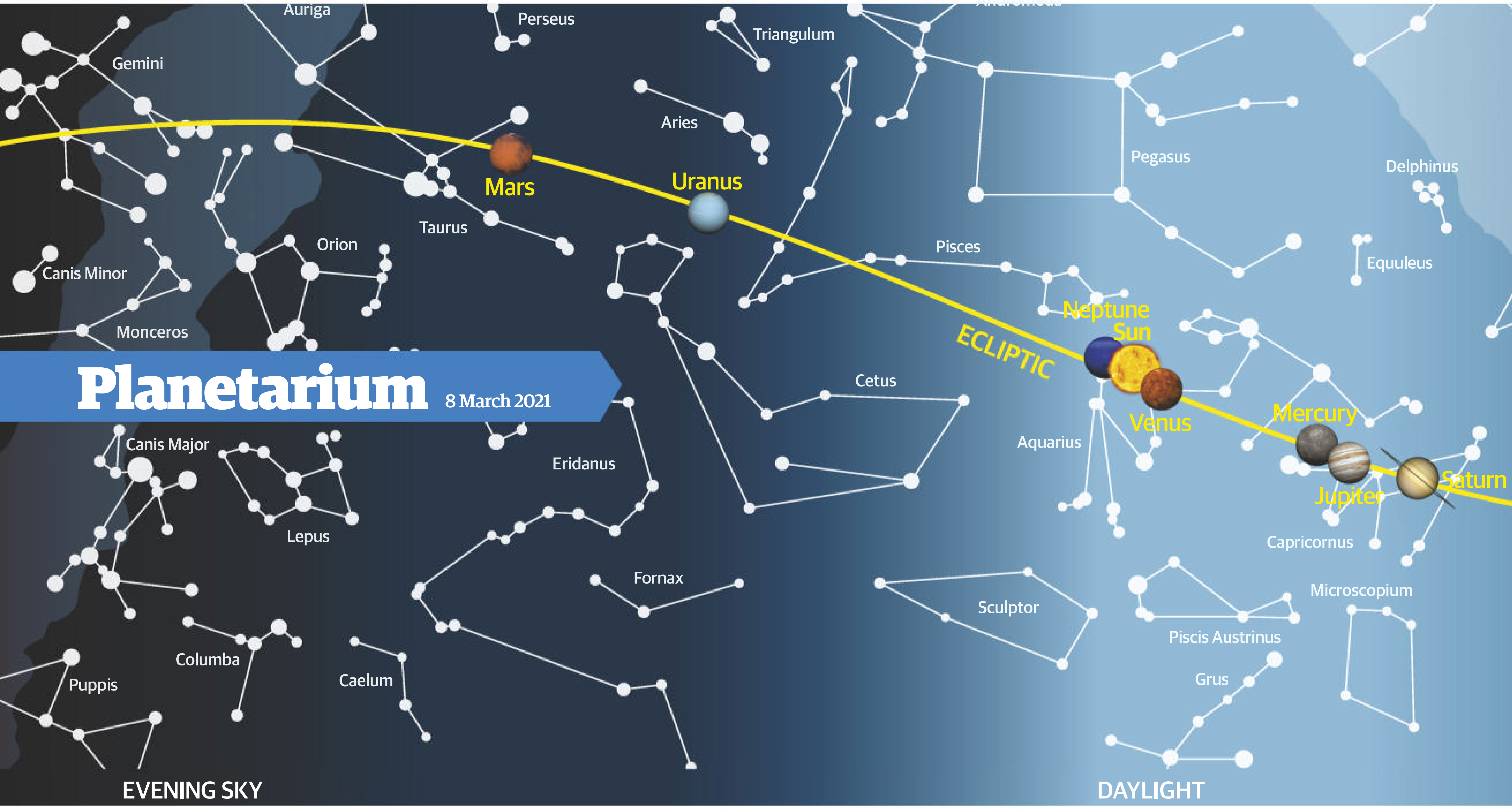
Declination tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it is from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, an object with a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

This is when a celestial body is in line with the Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter in the sky.



Planetarium

8 March 2021

Moon calendar

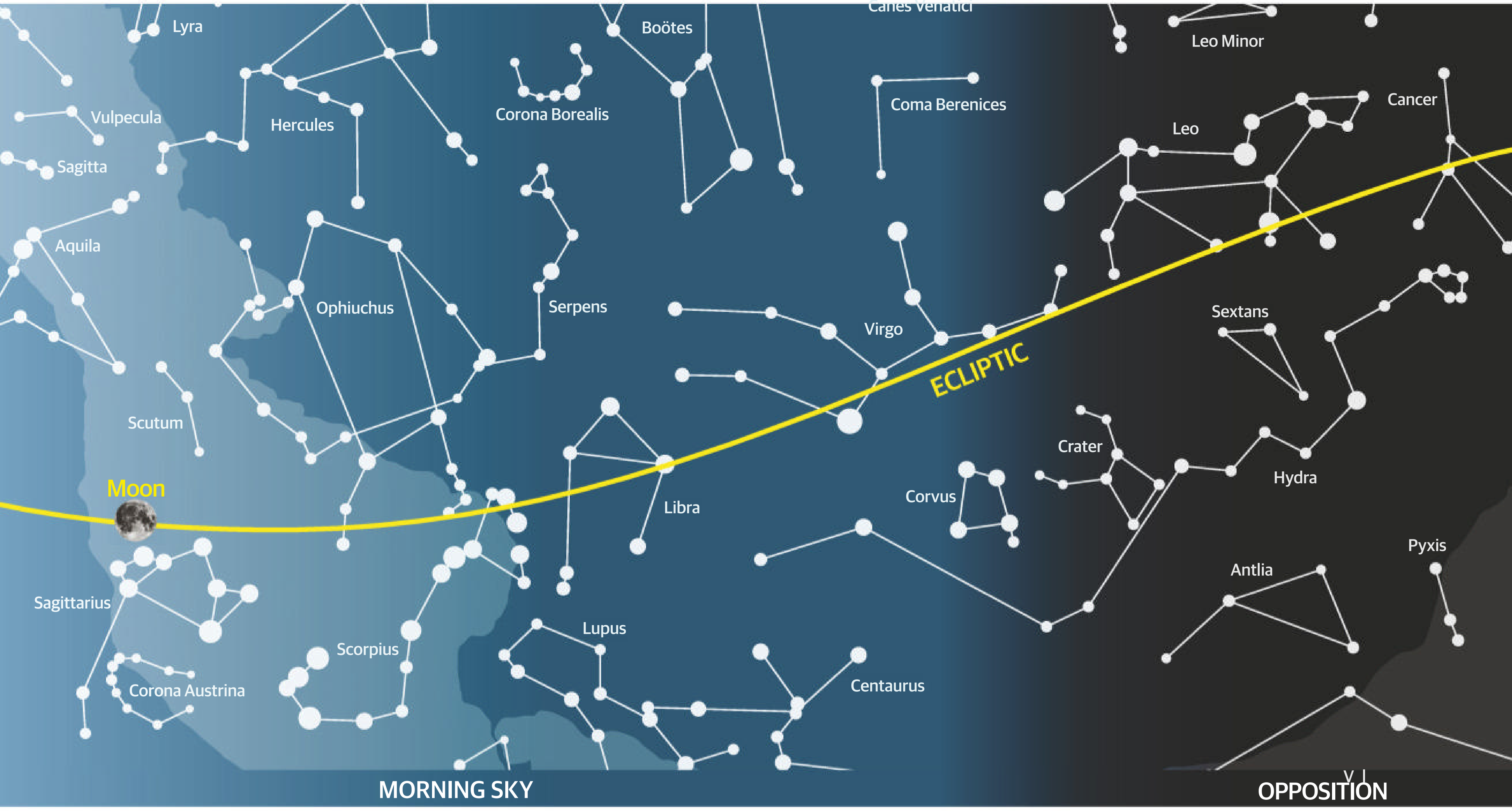
* The Moon does not pass the meridian on 26 February

25	FEB		97.4%	◡06:32	◠15:01
26	FEB		--:--%*	◡07:01	◠16:23
27	FEB	FM	99.7%	◡07:25	◠17:46
28	FEB		99.2%	◡07:45	◠19:11
1	MAR		95.8%	◡08:03	◠20:35
2	MAR		89.7%	◡08:21	◠22:00
3	MAR		81.2%	◡08:41	◠23:26
4	MAR		71.0%	◠09:03	◡--:--
5	MAR		59.6%	◠00:51	◡09:31
6	MAR	LQ	47.9%	◠02:12	◡10:08
7	MAR		36.5%	◠03:26	◡10:55
8	MAR		25.9%	◠04:26	◡11:55
9	MAR		16.8%	◠05:14	◡13:04
10	MAR		9.5%	◠05:49	◡14:19
11	MAR		4.2%	◠06:15	◡15:35
12	MAR		1.1%	◠06:36	◡16:49
13	MAR	NM	0.2%	◠06:53	◡18:01
14	MAR		1.4%	◠07:08	◡19:12
15	MAR		4.5%	◠07:22	◡20:21
16	MAR		9.4%	◠07:36	◡21:30
17	MAR		15.8%	◠07:52	◡22:38
18	MAR		23.5%	◠08:10	◡23:47
19	MAR		32.2%	◡--:--	◠08:29
20	MAR		41.6%	◡00:55	◠09:00
21	MAR	FQ	51.6%	◡02:00	◠09:57
22	MAR		61.7%	◡02:58	◠10:24
23	MAR		71.6%	◡03:48	◠11:24
24	MAR		80.9%	◡04:29	◠12:35
25	MAR		88.9%	◡05:01	◠13:53

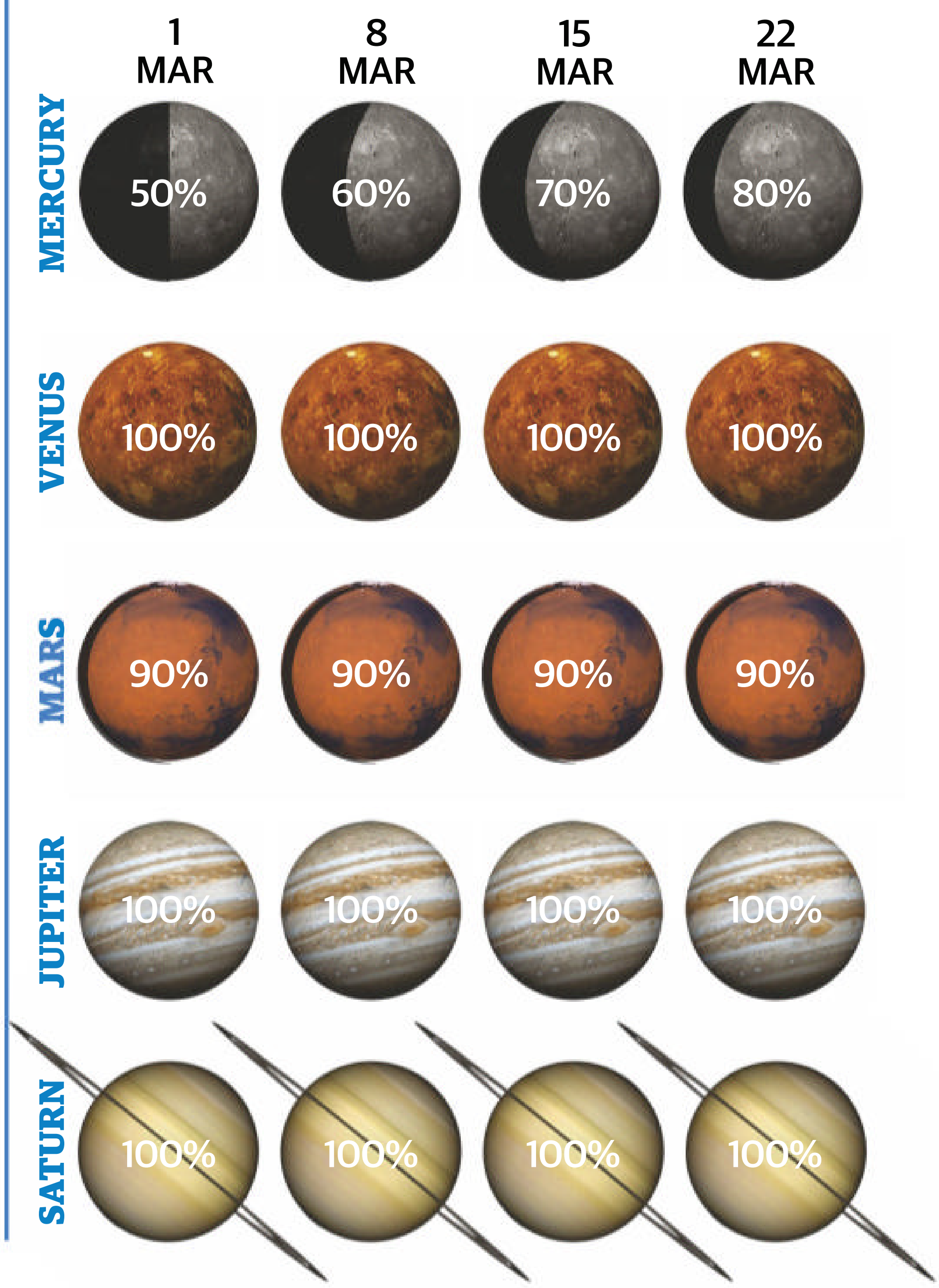
%	Illumination
◠	Moonrise time
◡	Moonset time

FM	Full Moon
NM	New Moon
FQ	First quarter
LQ	Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

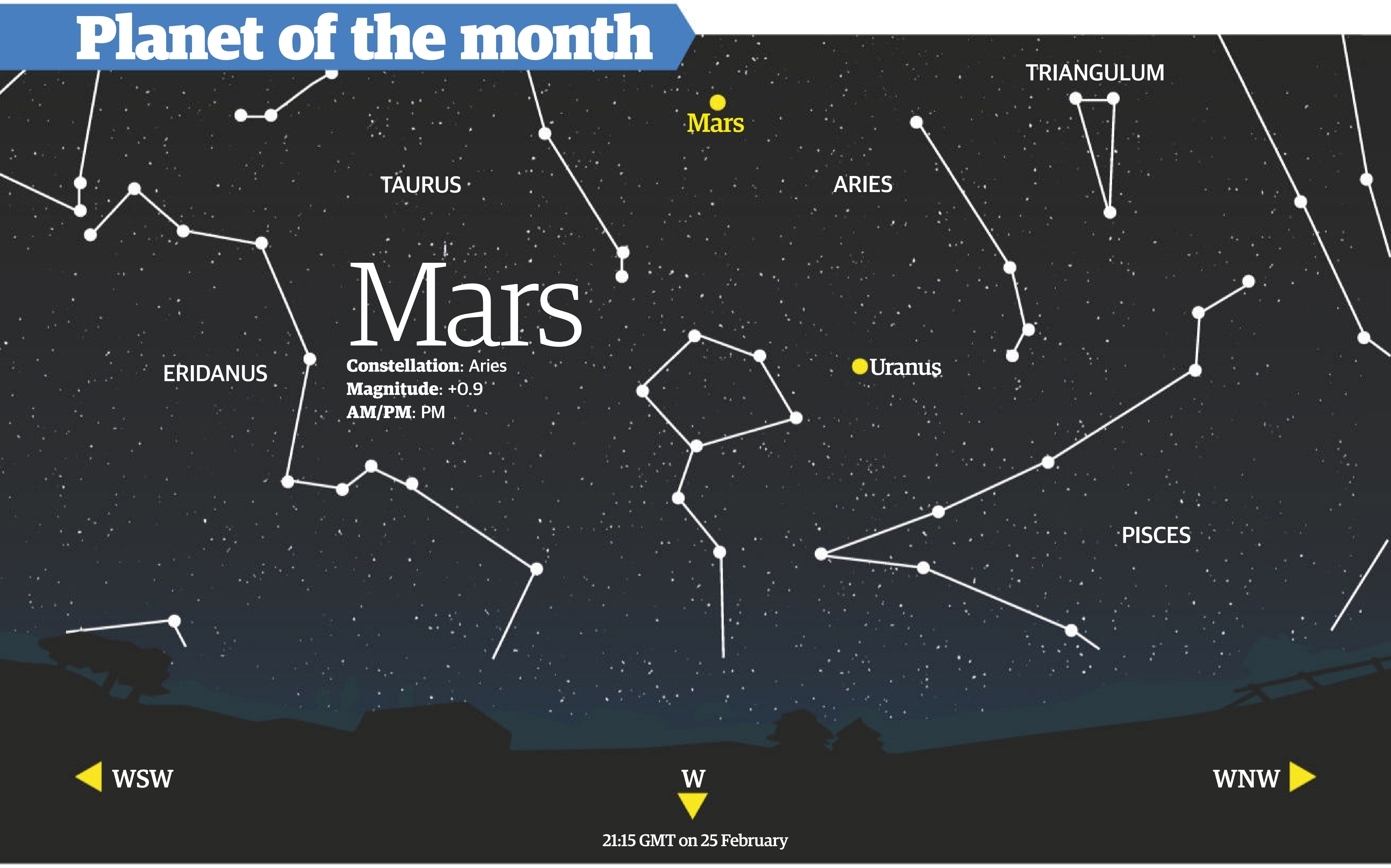
All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	25 FEB	20h 54m 33s	-16° 02' 10"	Capricornus	+0.3	05:54	15:13
	1 MAR	21h 04m 31s	-16° 11' 29"	Capricornus	+0.2	05:50	15:06
	8 MAR	21h 31m 06s	-15° 26' 47"	Capricornus	+0.0	05:44	15:10
	15 MAR	22h 04m 51s	-13° 30' 38"	Aquarius	-0.0	05:39	15:27
	22 MAR	22h 42m 51s	-10° 29' 07"	Aquarius	-0.1	05:33	15:53
VENUS	25 FEB	22h 06m 30s	-13° 01' 08"	Aquarius	-3.9	06:49	16:42
	1 MAR	22h 25m 41s	-11° 17' 22"	Aquarius	-3.9	06:43	16:55
	8 MAR	22h 58m 40s	-08° 04' 36"	Aquarius	-3.9	06:32	17:17
	15 MAR	23h 31m 03s	-04° 41' 18"	Aquarius	-3.9	06:19	17:39
	22 MAR	00h 03m 03s	-01° 11' 43"	Pisces	-3.9	06:06	18:01
MARS	25 FEB	03h 31m 35s	+20° 32' 32"	Taurus	+0.9	09:13	01:11
	1 MAR	03h 41m 08s	+21° 05' 30"	Taurus	+0.9	09:03	01:08
	8 MAR	03h 58m 10s	+21° 58' 46"	Taurus	+1.0	08:46	01:03
	15 MAR	04h 15m 35s	+22° 45' 54"	Taurus	+1.1	08:31	00:59
	22 MAR	04h 33m 21s	+23° 26' 20"	Taurus	+1.2	08:16	00:54
JUPITER	25 FEB	21h 12m 11s	-16° 45' 25"	Capricornus	-2.0	06:16	15:26
	1 MAR	21h 15m 51s	-16° 29' 31"	Capricornus	-2.0	06:03	15:16
	8 MAR	21h 22m 07s	-16° 01' 41"	Capricornus	-2.0	05:39	14:57
	15 MAR	21h 28m 12s	-15° 34' 02"	Capricornus	-2.0	05:14	14:39
	22 MAR	21h 34m 04s	-15° 06' 46"	Capricornus	-2.0	04:50	14:19
SATURN	25 FEB	20h 41m 08s	-18° 46' 14"	Capricornus	+0.7	05:57	14:43
	1 MAR	20h 42m 54s	-18° 39' 53"	Capricornus	+0.7	05:43	14:30
	8 MAR	20h 45m 53s	-18° 29' 04"	Capricornus	+0.7	05:17	14:07
	15 MAR	20h 48m 43s	-18° 18' 45"	Capricornus	+0.7	04:51	13:43
	22 MAR	20h 51m 21s	-18° 09' 03"	Capricornus	+0.8	04:25	13:19

This month's planets

As NASA's Perseverance rover touches down on Mars this February, the Red Planet is also a great target for observers not long after sunset

Planet of the month



Mars

Constellation: Aries
Magnitude: +0.9
AM/PM: PM

21:15 GMT on 25 February

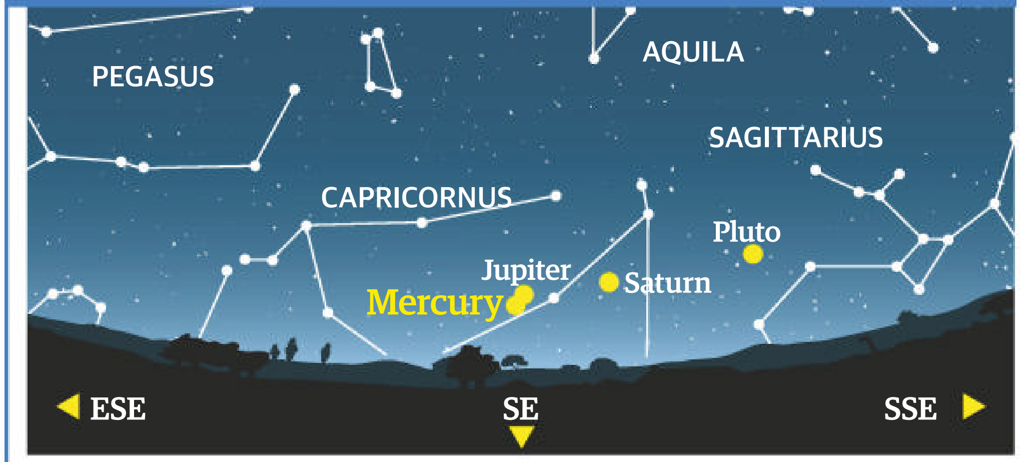
Our planet of the month is Mars, not just because it is an easy naked-eye object after sunset, but because it will be in the news a great deal as NASA's latest rover, Perseverance, begins its mission to look for signs of life on the Red Planet, having landed in Jezero crater on 18 February.

Mars is an evening object, looking like an orange 'star' to the naked eye. It can be found quite high in the southwest as soon as the sky begins to darken, in the busy constellation of Taurus, and will be visible until around 01:00. As our observing period begins, Mars will lie almost directly below the Pleiades star cluster. As the days pass, Mars will move up towards the cluster, shining a little closer to it each evening, and by 4 March the two will be less than three degrees apart, when they will be a beautiful sight through binoculars and small telescopes as well as clearly visible to the naked eye. Mars will then slide slowly past the Pleiades, drifting to their left, and by mid-March it will lie almost halfway between it and the neighbouring V-shaped Hyades star cluster, which forms the horns of the Bull.

On any clear night throughout this month, Mars will be a lovely sight close to two of the most famous star clusters in the sky, but cross your fingers especially tight for a clear sky on the evening of 19 March, when a waxing Moon will join the party, shining close to Mars and directly between the two star clusters. This gathering will be beautiful to scan with binoculars and small telescopes, and will be a prime target for many astrophotographers around the world too. If the camera on your phone has a night mode you should definitely try it on this celestial party; make sure your phone is held still as you take your photo or Mars and the stars around it will look like wobbly lines instead of pinpoints.

By the end of our observing period Mars will have moved further eastwards along the ecliptic and will be shining above the wickedly sharp horns of the Bull. By then it will have faded a little, and will be fainter than Aldebaran, the brightest star in the horns, which is a very similar orange colour to Mars.

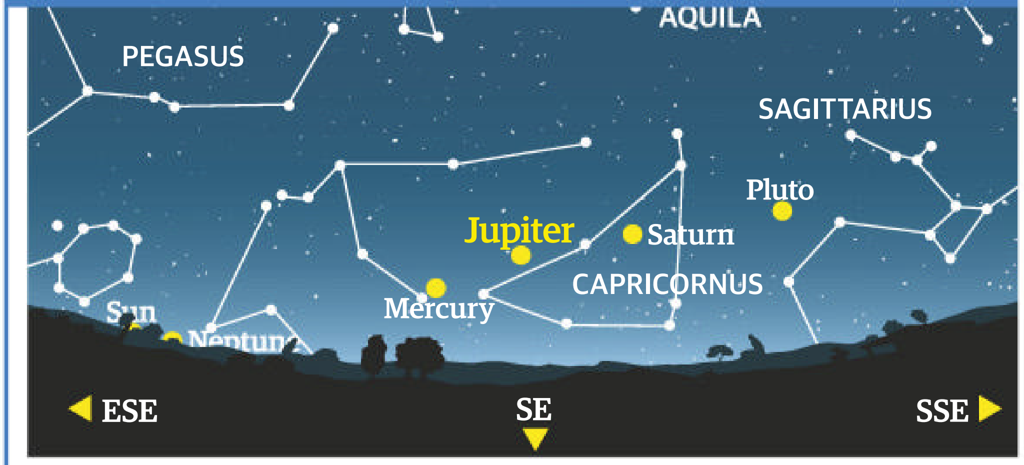
Mercury 06:30 GMT on 5 March



Constellation: Capricornus
Magnitude: +0.5
AM/PM: AM

At the start of our observing period Mercury is visible low in the east before sunrise, forming a triangle with brighter Jupiter and Saturn, but it will be hard to see in the bright dawn sky; you'll likely need binoculars to pick it out, but only look for it before sunrise or you risk damaging your eyes.

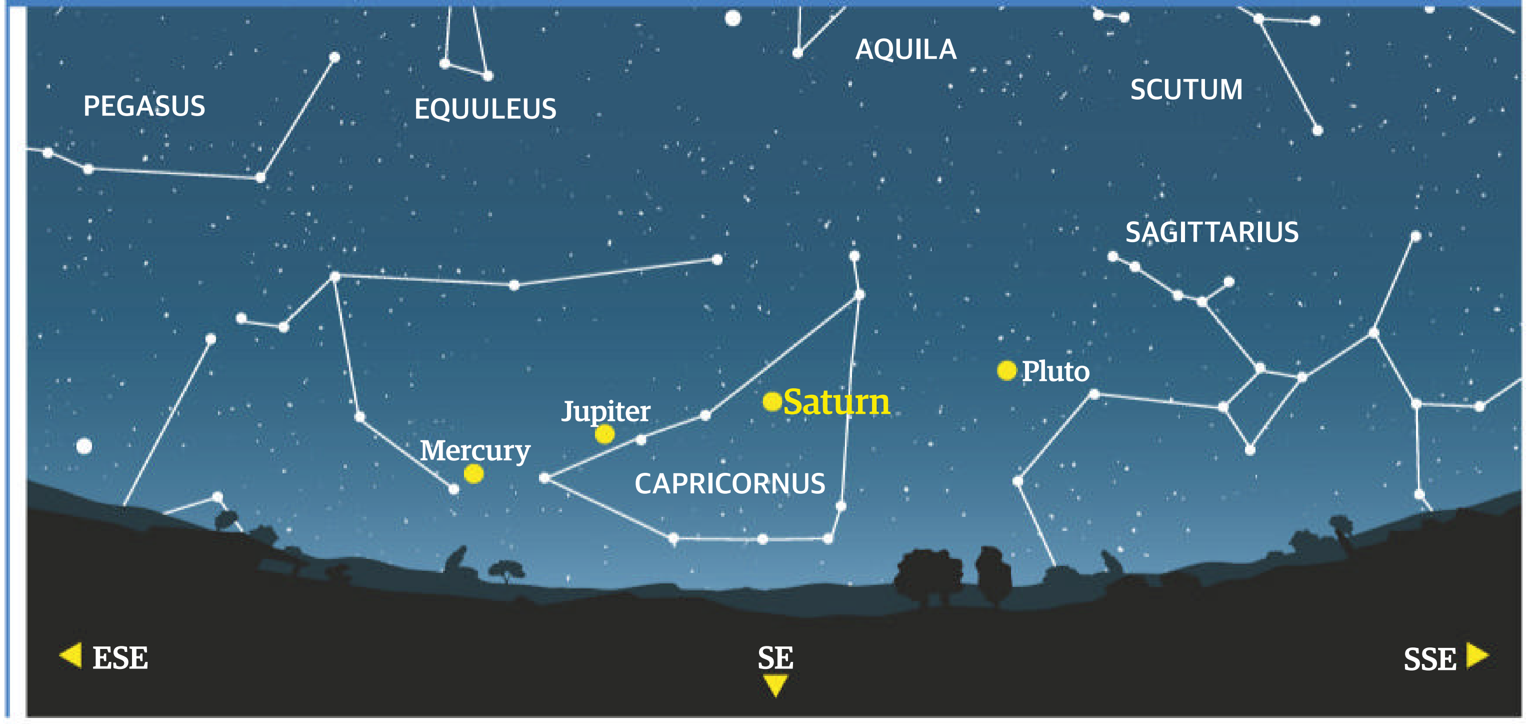
Jupiter 06:30 GMT on 14 March



Constellation: Capricornus
Magnitude: -2.0
AM/PM: AM

Jupiter is so low in the sky before sunrise that it will be hard to see without binoculars, and viewing prospects only worsen as the month progresses. The king of the Solar System will be close to both Mercury and Saturn in the sky, but only rising half an hour or so before the Sun makes it difficult to see.

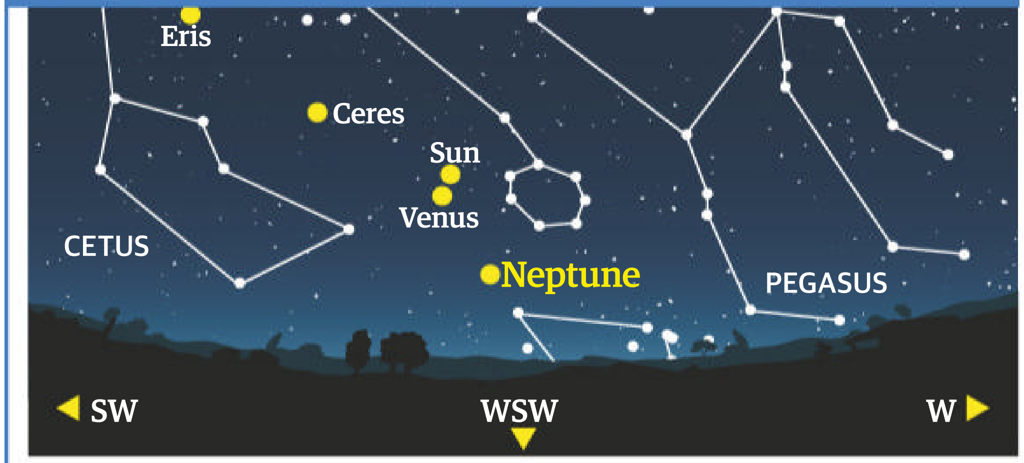
Saturn 06:30 GMT on 14 March



Constellation: Capricornus
Magnitude: +0.7
AM/PM: AM

Like neighbouring Jupiter, Saturn will be a morning object this month, but also like Jupiter it will be hard to see because it will be rising only shortly before sunrise and will be hard to pick out from the bright sky. As the month progresses Saturn and Jupiter will draw apart from each other, but will remain in such close proximity to the Sun that they will be hard to see. It's better to remember how much more obvious and beautiful they looked at the end of last year and leave them to fade into the dawn this month. We'll see them much better later in the year.

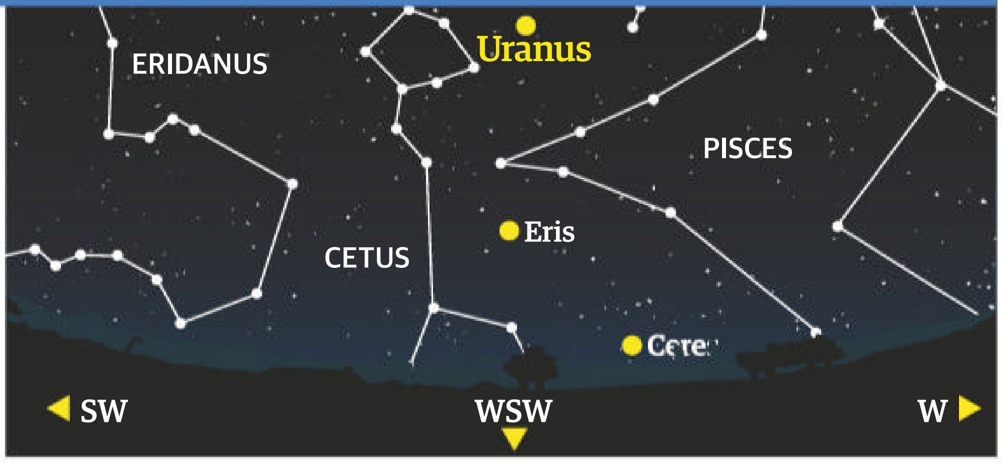
Neptune 16:15 GMT on 21 March



Constellation: Aquarius
Magnitude: +8.0
AM/PM: PM

Neptune, the farthest planet from the Sun, is an evening object this month, but at the start of our observing period it is so low after sunset, and so close to the Sun, that it will be hard to see. You need at least a pair of binoculars and more likely a telescope to see it even in a dark sky.

Uranus 18:30 GMT on 17 March



Constellation: Aries
Magnitude: +5.8
AM/PM: PM

Uranus will be visible in the evening sky this month, but you'll need a pair of binoculars or a small telescope to see it. The penultimate planet is technically a naked-eye object, visible from the end of twilight to after midnight down to the lower right of Mars, but you'll need to know exactly where to look.

Moon tour

Vallis Alpes: The Alpine Valley

Stare down into one of the Moon's captivating crevices

When you think about the Moon, certain features spring to mind. There are craters, the gaping holes left behind when huge chunks of asteroid came hurtling in from space and slammed into the Moon, blasting pits out of the surface. Then there are the lunar seas, or maria, which are vast plains of dark, ancient lava that once flowed over the Moon's surface, slopping over and covering even older craters and hills. But there is a third type of lunar feature that is often overlooked, mainly because there are far fewer of them – the lunar valleys. This month we're going to show you where to find possibly the most famous and striking of all the crevices on the Moon.

Top tip!

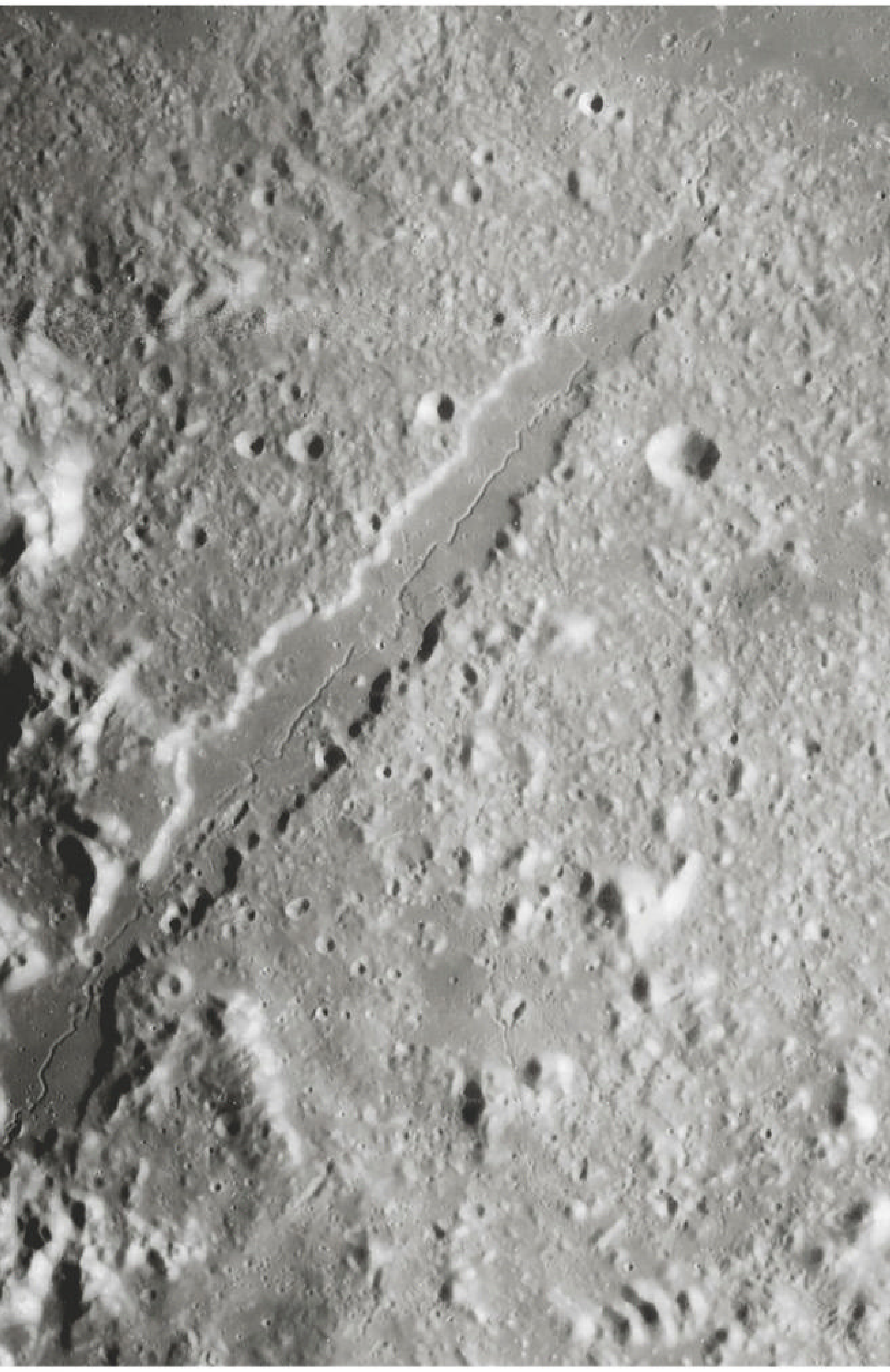
The valley will be at its best when it is near the terminator, the line between lunar night and day.

Look towards the top of the Moon on any night between its first quarter and waning gibbous phases and you'll see the dark, oval spot of Plato. It's easy to see in binoculars and a lovely sight in a telescope. Look a little more closely and just to its right you'll see what looks like a short, straight, dark line drawn at an almost-diagonal angle across a brighter, rougher area. This is Vallis Alpes, or the Alpine Valley, and it cuts across the Alpine Mountains like a scar.

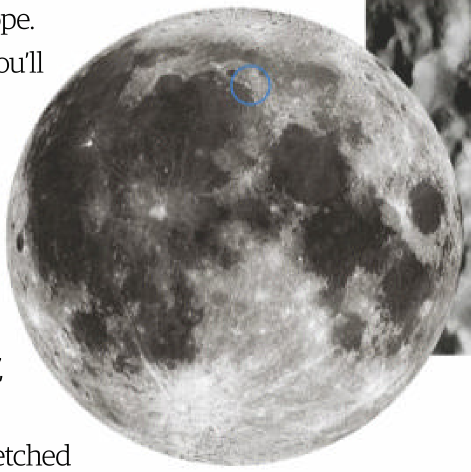
Alpes Vallis was first observed by the Italian astronomer Francesco Bianchini in 1727, and was officially named by the International Astronomical Union in 1961. Of all the valleys etched across the face of the Moon, it is the easiest to see, and a most striking visual subject through a telescope eyepiece. Although some lunar geologists think it might be a crack in the crust caused by the enormous, Moon-shuddering impact that formed the huge Mare Imbrium, most seem to agree it is a graben, a less dramatic geological feature that is essentially an area of the crust that has dropped down between two faults, creating a valley. Vallis Alpes is over 160 kilometres (99 miles) long, stretching between Mare Imbrium to the south, where it ends in a jumble of jagged mountains, and the flat plain of Mare Frigoris to the north. Long and thin, in some regions along its length the valley opens up more widely; some parts are almost 15 kilometres (9.3 miles) across.

Running down the length of the valley, kinked in several places, is a much narrower rille, which looks like a crack or a scratch etched in its grey floor. This rille is a stunning sight in a telescope fitted with a high-power eyepiece, meandering around the many small craters spattered across the valley floor. Because of its twists and turns, the rille is actually longer than the valley, and moments of clear seeing show many pits and slumped areas of its own, making it a very rewarding target in its own right.

At the start of our observing period it is almost fully illuminated by the overhead Sun, so it is reduced to a mere dark line with no surface relief or detail whatsoever, and by full Moon on 28 February the valley is almost completely washed out. By 3 March the situation changes. As the terminator – the line between lunar night and day – approaches, the valley will start to become more visible. Its walls will begin to cast shadows, making it stand out more clearly, and on 5 March the valley will be a striking sight through a telescope, standing out starkly against the surface, and really will look like a long crack in the Moon, with an even thinner hairlike crack running down its centre. On 6 March the valley will be plunged into shadow again, and won't reappear until 20 March when the Sun will reappear over its local horizon and it will be lit at a low angle. By 24 March the valley will be fully on view once again.

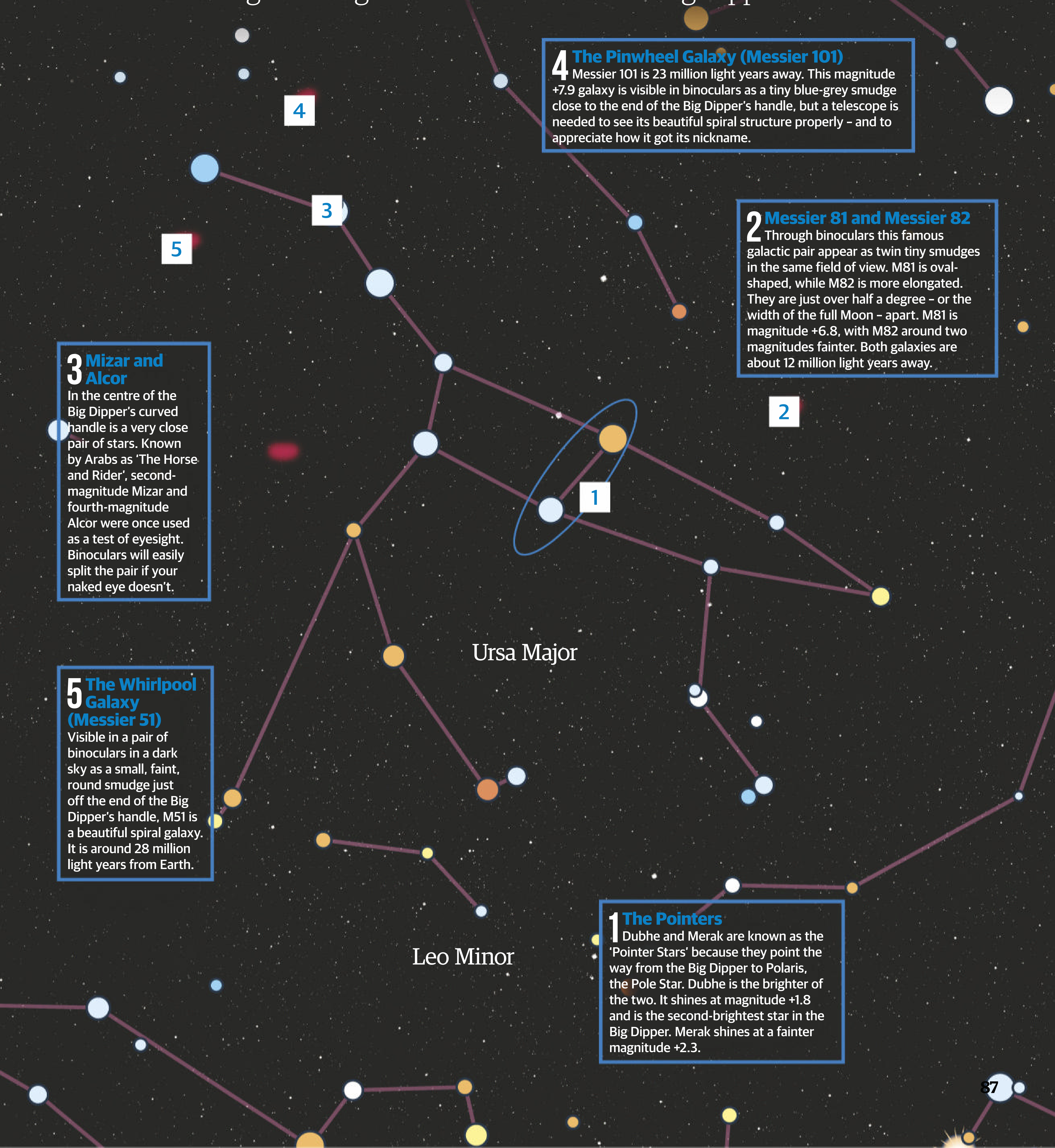


© NASA



Naked eye & binocular targets

The start of spring is one of the best times to wander around the wonders neighbouring the familiar stars of the Big Dipper



4 The Pinwheel Galaxy (Messier 101)

Messier 101 is 23 million light years away. This magnitude +7.9 galaxy is visible in binoculars as a tiny blue-grey smudge close to the end of the Big Dipper's handle, but a telescope is needed to see its beautiful spiral structure properly – and to appreciate how it got its nickname.

2 Messier 81 and Messier 82

Through binoculars this famous galactic pair appear as twin tiny smudges in the same field of view. M81 is oval-shaped, while M82 is more elongated. They are just over half a degree – or the width of the full Moon – apart. M81 is magnitude +6.8, with M82 around two magnitudes fainter. Both galaxies are about 12 million light years away.

3 Mizar and Alcor

In the centre of the Big Dipper's curved handle is a very close pair of stars. Known by Arabs as 'The Horse and Rider', second-magnitude Mizar and fourth-magnitude Alcor were once used as a test of eyesight. Binoculars will easily split the pair if your naked eye doesn't.

5 The Whirlpool Galaxy (Messier 51)

Visible in a pair of binoculars in a dark sky as a small, faint, round smudge just off the end of the Big Dipper's handle, M51 is a beautiful spiral galaxy. It is around 28 million light years from Earth.

1 The Pointers

Dubhe and Merak are known as the 'Pointer Stars' because they point the way from the Big Dipper to Polaris, the Pole Star. Dubhe is the brighter of the two. It shines at magnitude +1.8 and is the second-brightest star in the Big Dipper. Merak shines at a fainter magnitude +2.3.

Pleiades (Messier 45) and IC 353

Deep sky challenge

Taurus' treasures

There's more to the Bull than the glittering Hyades and Pleiades star clusters

Many constellations are famous for one or two special deep-sky objects. Summer favourite Lyra is famous for the smoky circle of the Ring Nebula (Messier 57), while in winter Orion's Orion Nebula and fainter Horsehead Nebula always delight observers, and to their east the squashed box of Cancer is home to Messier 44, the Beehive Cluster.

Mention Taurus to a deep-sky observer and they will wax lyrical about the beauty of its two large, bright open star clusters: the V-shaped Hyades cluster and the 'mini Big Dipper' of the Pleiades cluster. However, there are other deep-sky objects hidden around those that are well worth taking the time to find in your telescope eyepiece.

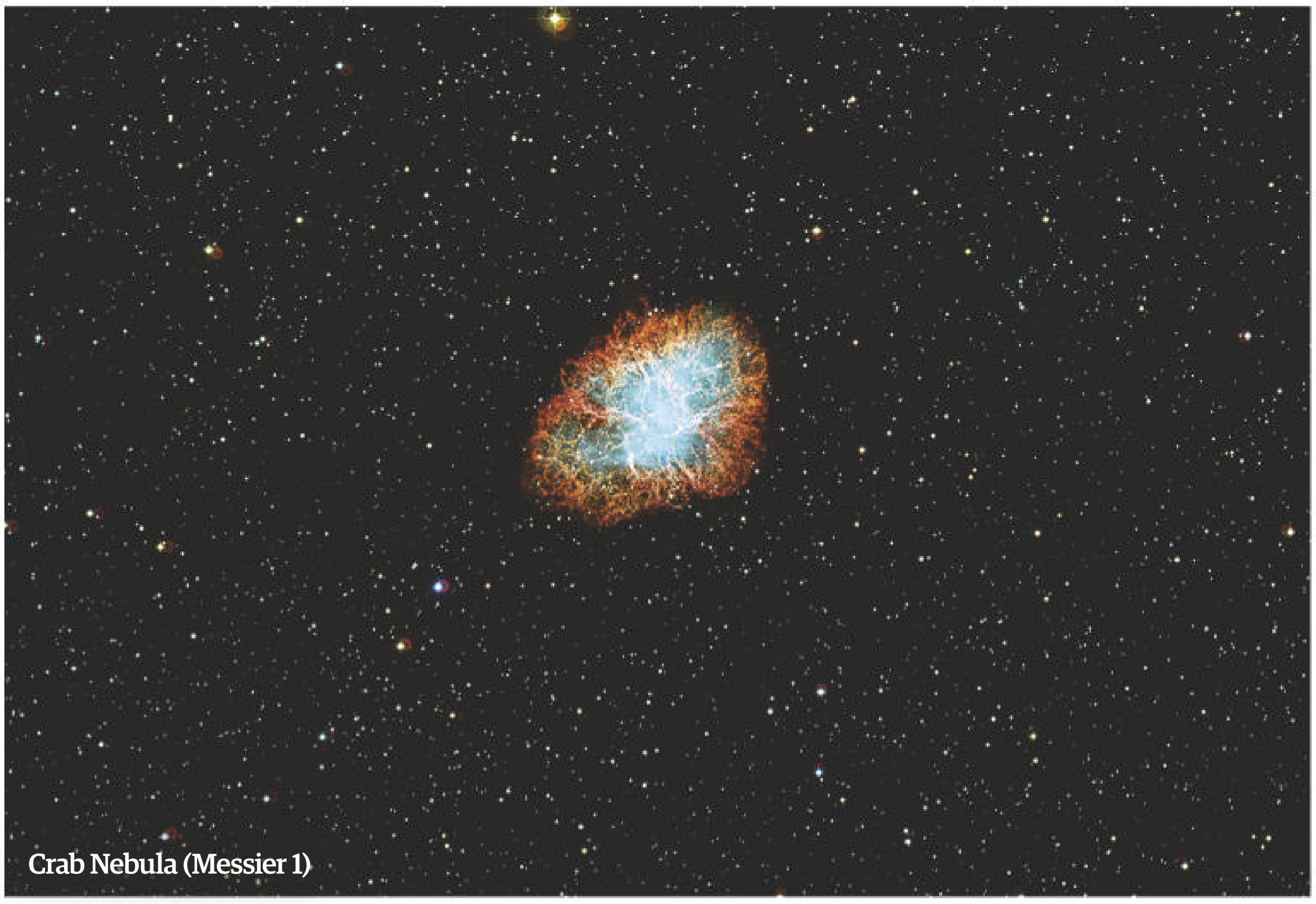
The Crab Nebula (Messier 1) is rightly famous, but its misty beauty is reserved for observers blessed with dark skies; if you live somewhere with skies that are spoiled by even low levels of light pollution you'll struggle to find it. The other objects listed this month will all require medium- or large-aperture telescopes to see them, and dark skies with no Moon to wash out their faint light, but they're a welcome diversion 'off the beaten track' if you can drag your telescope away from the beautiful jewelled sprays of the Hyades and Seven Sisters. As spring approaches, why not swing your telescope towards Taurus and find something different for a change.

NGC 1514

Source: Wikipedia Commons © Oleg milantiev

> “THE CRAB NEBULA’S MISTY BEAUTY IS RESERVED FOR OBSERVERS BLESSED WITH DARK SKIES”

Sourece: Wikipedia Commons © Juan lacruz



Crab Nebula (Messier 1)

© ESO

1 NGC 1817

This faint and sparse open star cluster is close enough to NGC 1807 that together the two look like a double cluster. Both will fit in a low-power eyepiece, but each is little more than a spatter of a couple dozen stars.

4 NGC 1615

This 12th-magnitude elliptical galaxy close to the ‘horns’ of the Hyades looks like a small, slim oval smudge through large telescopes under dark skies. It lies about 154 million light years from the Milky Way.

2 IC 353

Just to the north of the Pleiades lies IC 353, a gaseous nebula 24 light years wide and 460 light years away. You’ll need a small- to medium-aperture telescope to see it as a short, faint wisp of nebulosity.

5 Crab Nebula (Messier 1)

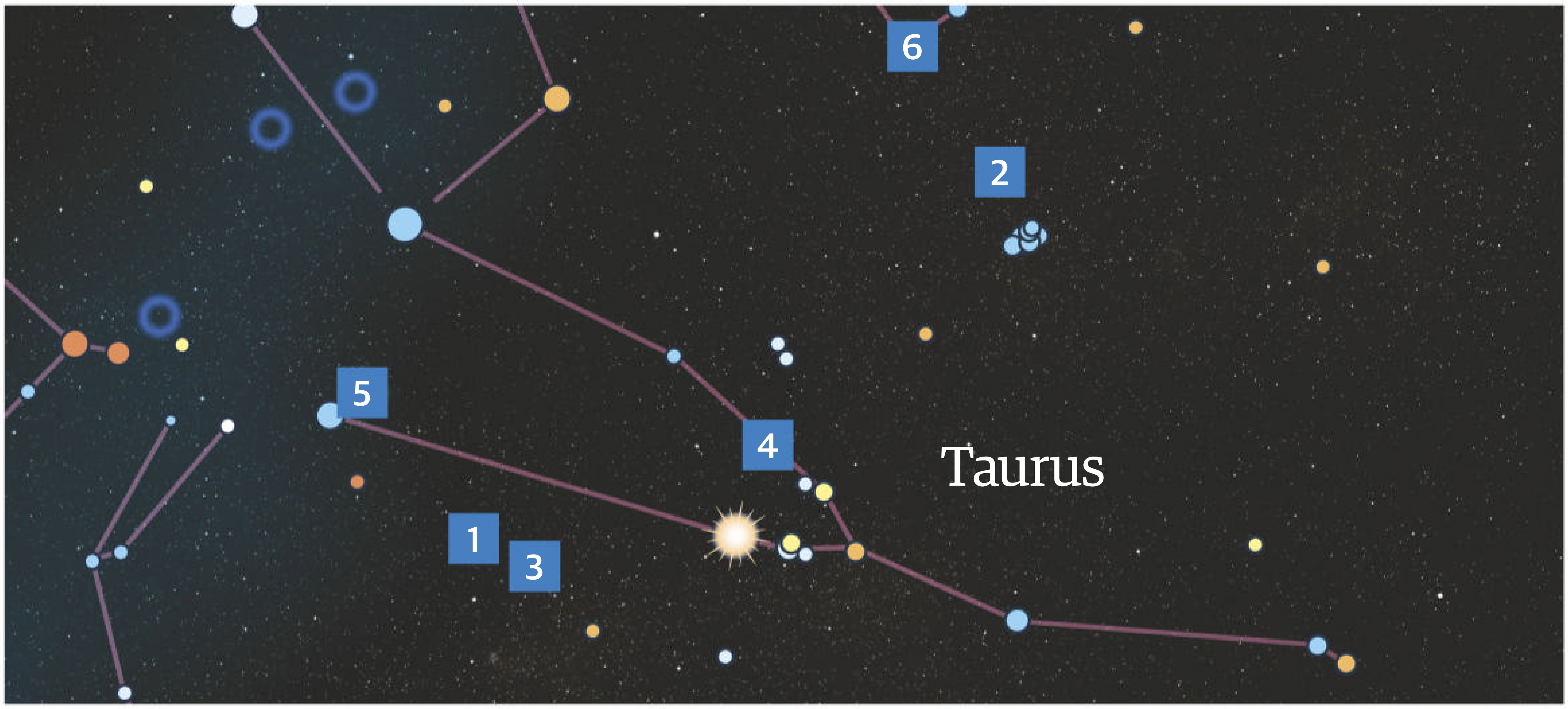
Best seen in a large telescope, Messier 1 is the most famous supernova remnant in the sky, but at magnitude +8.4 and with a low surface brightness and small size, any light pollution or moonlight will drown it out.

3 NGC 1807

Little more than a loose spray of faint stars pressed up close against Taurus’ border with Orion, this +7.0 open cluster requires high magnification to isolate its members from the many background stars.

6 NGC 1514

With its faint outer edge and bright interior blobs and clumps, some think this magnitude +10.9 planetary nebula resembles a tiny open flower. You’ll need a medium- or large-aperture telescope to see it.



The Northern Hemisphere

The spring constellations are teeming with galaxies for deep-sky enthusiasts

As we move into spring, observers are able to enjoy the season's galaxies, many of which are circumpolar, throughout the evening. Those found in Virgo and Ursa Major are ideal for those with at least a small telescope. Fans of globular star clusters are in for a treat this month, as the Great Globular Cluster in Hercules (Messier 13), which shines at magnitude +5.9, and its +6.5 neighbour, Messier 92, will not set until around 05:00.

If you're a fan of observing using binoculars, there are a variety of targets to be observed, such as the bright star system Capella in the constellation of Auriga, as well as double stars Mizar and Alcor in the handle of the Plough, or Big Dipper.

Using the sky chart

This chart is for use at 22:00 (GMT) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

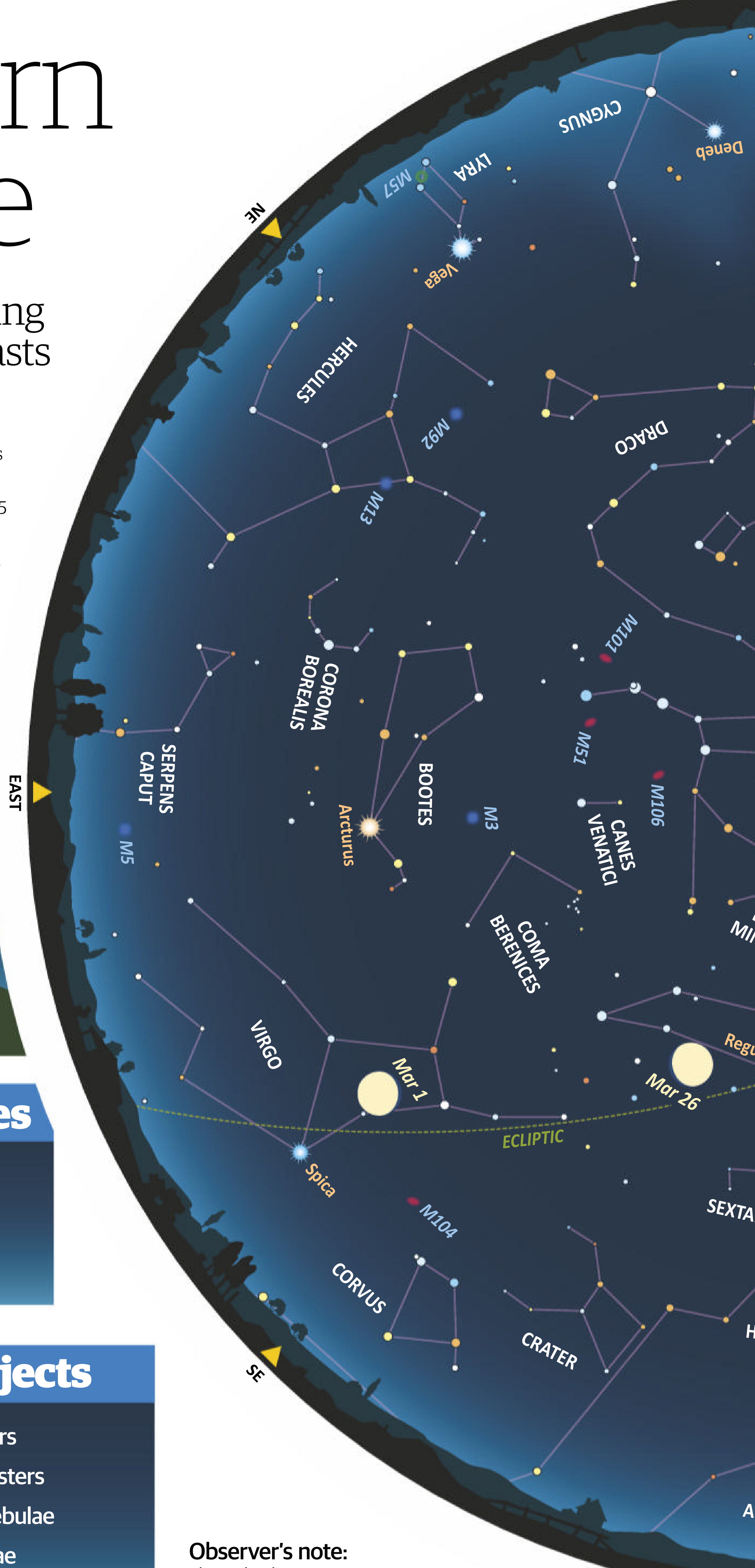
- ✸ Sirius (-1.4)
- ✸ -0.5 to 0.0
- ✸ 0.0 to 0.5
- ✸ 0.5 to 1.0
- ✸ 1.0 to 1.5
- • 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- • 3.0 to 3.5
- · 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- ◉ Variable star

Spectral types

✸ ●	O-B	✸ ●	G
✸ ●	A	✸ ●	K
✸ ●	F	✸ ●	M

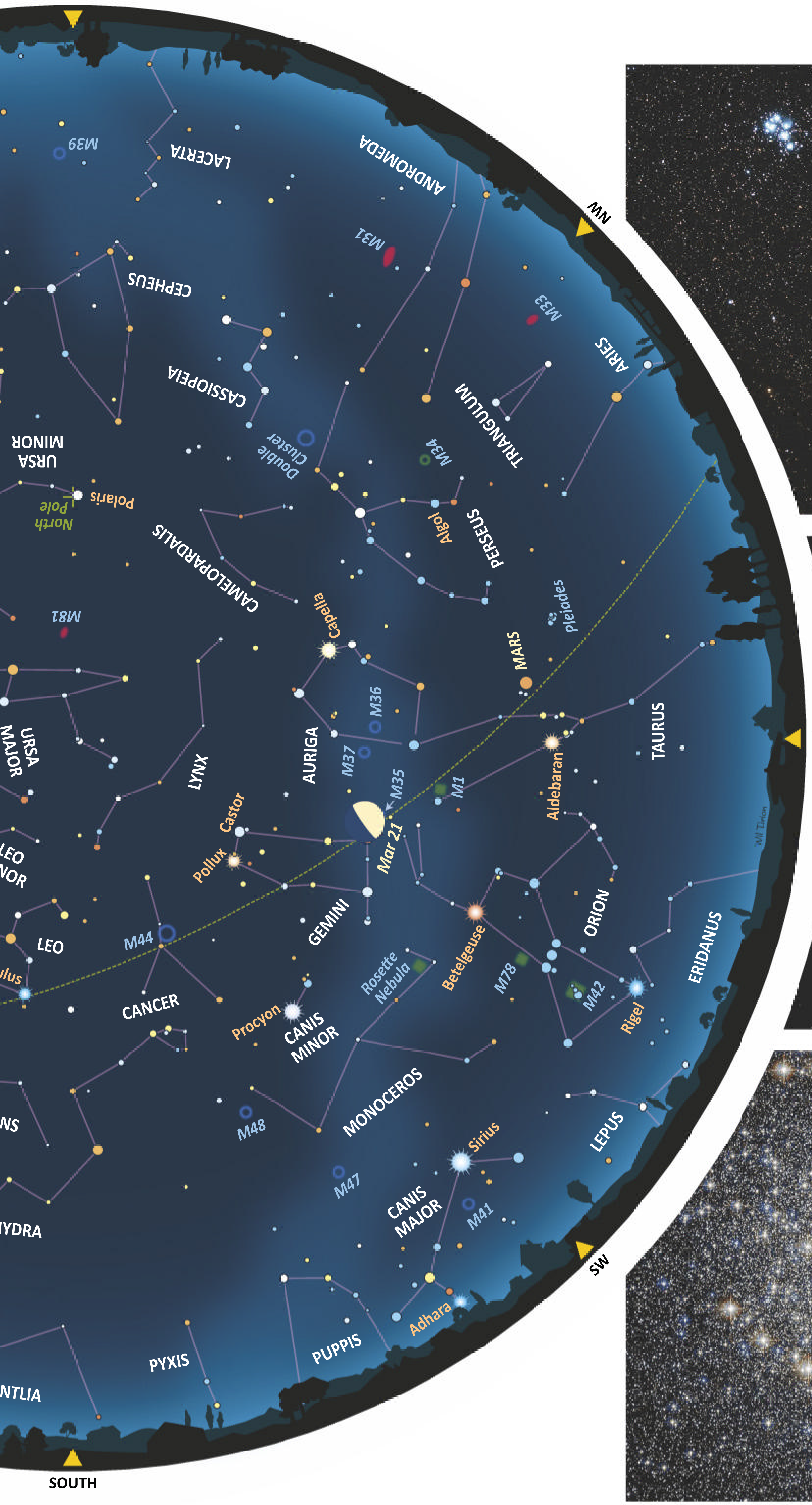
Deep-sky objects

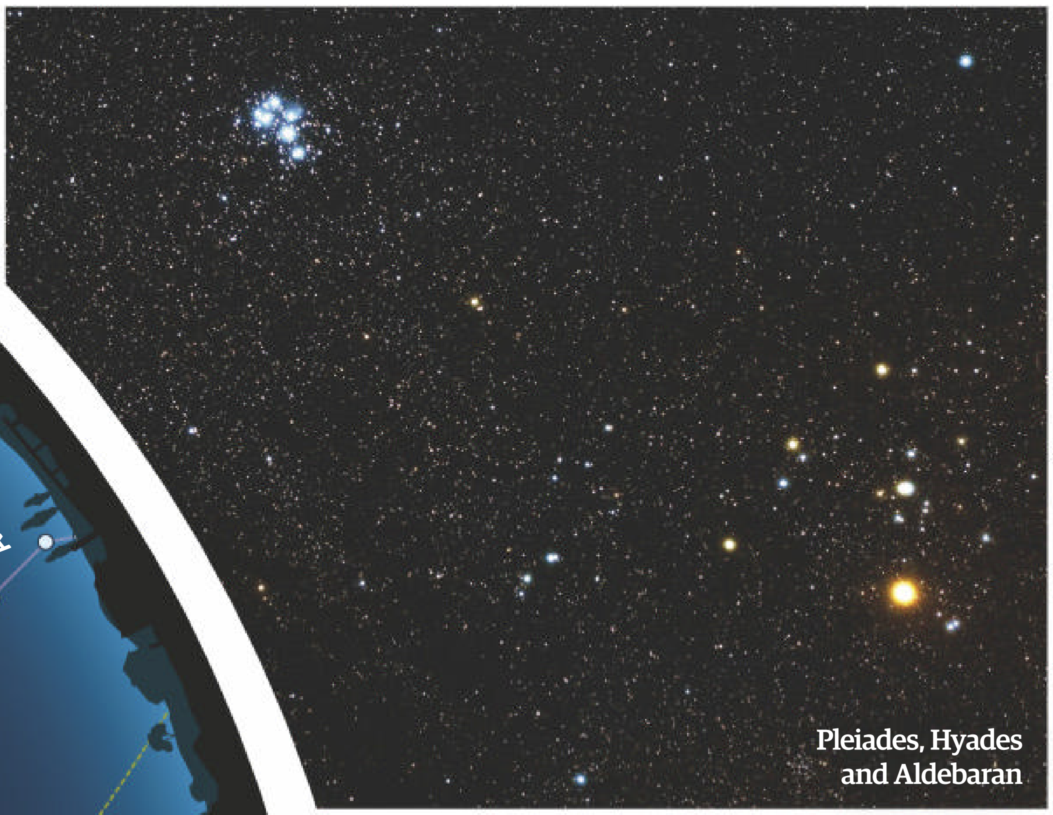
- ○ ○ Open star clusters
- ● ● Globular star clusters
- ■ ■ Bright diffuse nebulae
- ○ ○ Planetary nebulae
- ● ● Galaxies



Observer's note:
The night sky as it appears on 17 March 2021 at approximately 22:00 (GMT)

The Northern Hemisphere




Pleiades, Hyades and Aldebaran

Source: Wikipedia Commons © Giuseppe Donatiello

Pinwheel Galaxy (Messier 101)

© NASA, ESA

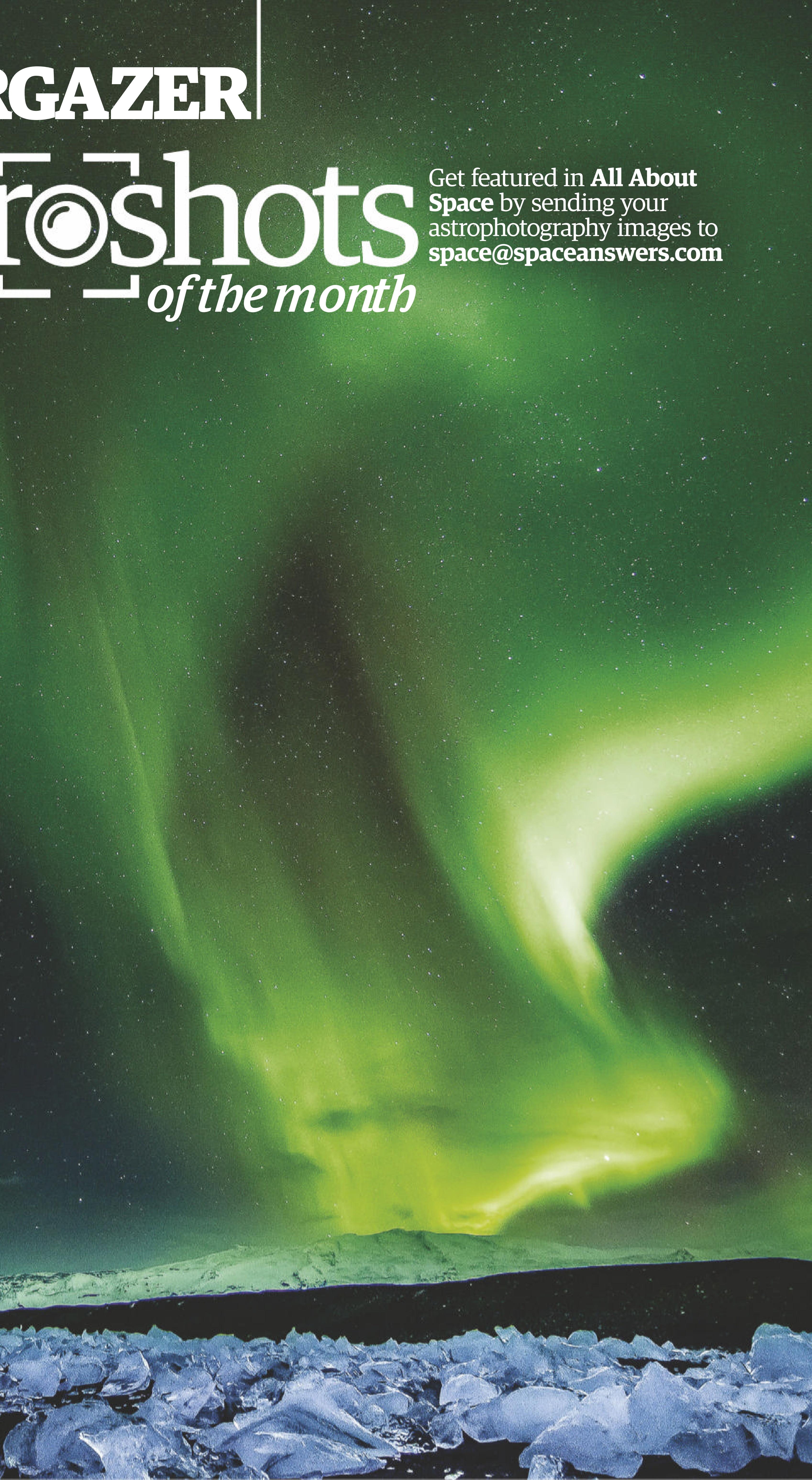
Messier 92

© NASA, ESA & Hubble

Astroshots of the month

Get featured in **All About Space** by sending your astrophotography images to **space@spaceanswers.com**

Right: The northern lights (aurora borealis)

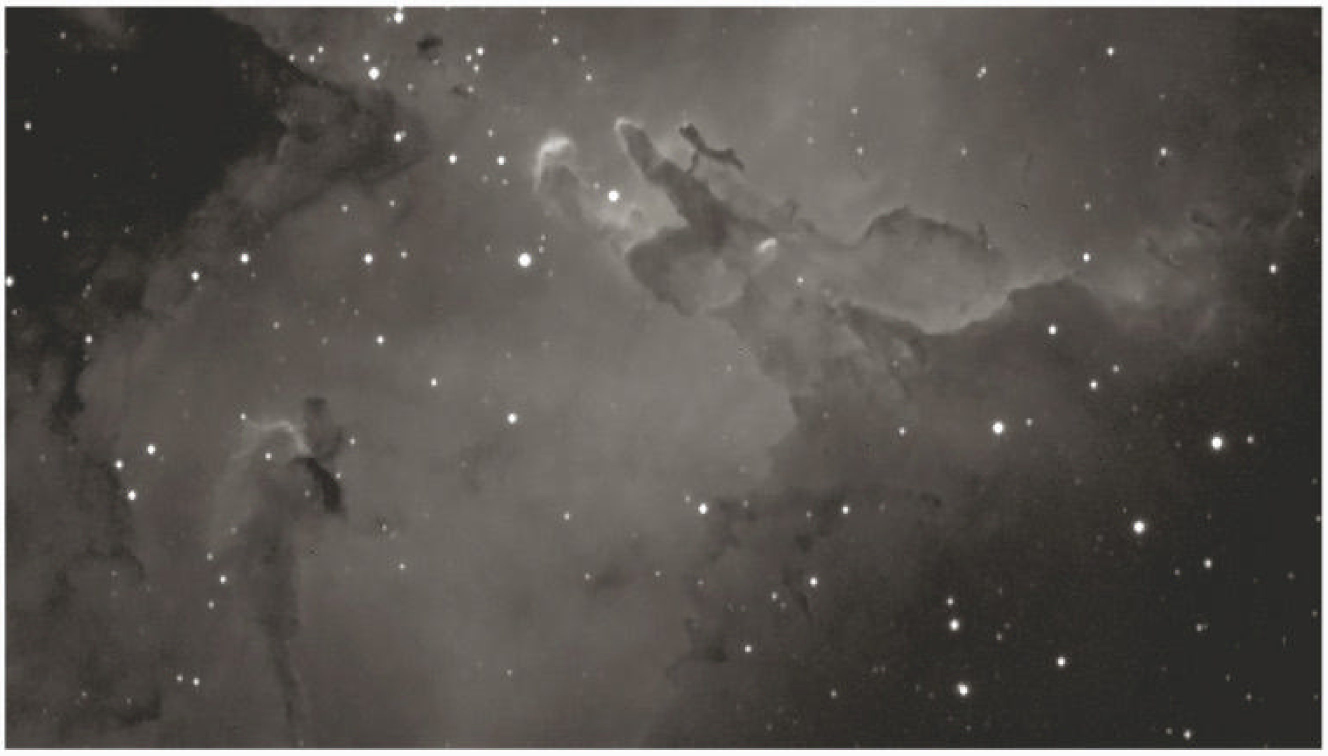


Cory Schmitz

Location: Johannesburg, South Africa

Telescope: Officina Stellare Hiper APO, Vixen ED80Sf and Orion 8" Astrograph

"Ever since space camp and a model rocketry obsession as a child, I've been enamoured by the universe. In 2011 I purchased my first telescope, a ten-inch Dobsonian, and one year later took my first deep-space photo of the Great Globular Cluster in Hercules (M13) using a DIY equatorial platform. Since then I've imaged deep-sky objects, the lunar surface and planetary targets, wide-field landscapes and timelapses."



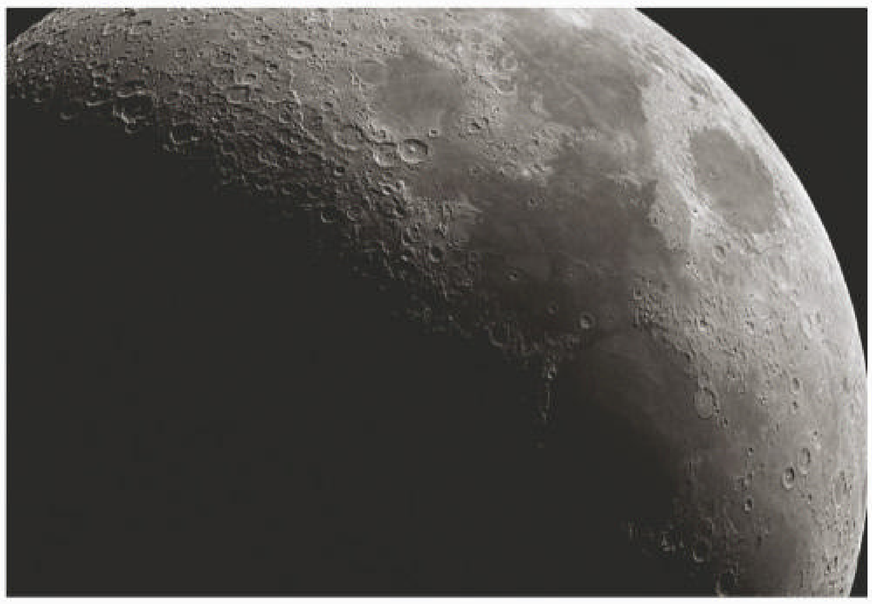
Bill Schlosser

Location: Michigan, US

Telescope: Meade LX850 14" Schmidt-Cassegrain, Astro-Tech AT65EDQ astrograph, Orion 7" Maksutov-Cassegrain

"When I first saw Jupiter through an old Meade eight-inch reflector, it was a life-changing moment for me. I joined the US Navy after graduating from high school and was stationed in San Diego, California. Being on board a darkened ship in the middle of the Pacific Ocean is something everyone should experience – I witnessed the Milky Way being so bright that it was casting shadows!

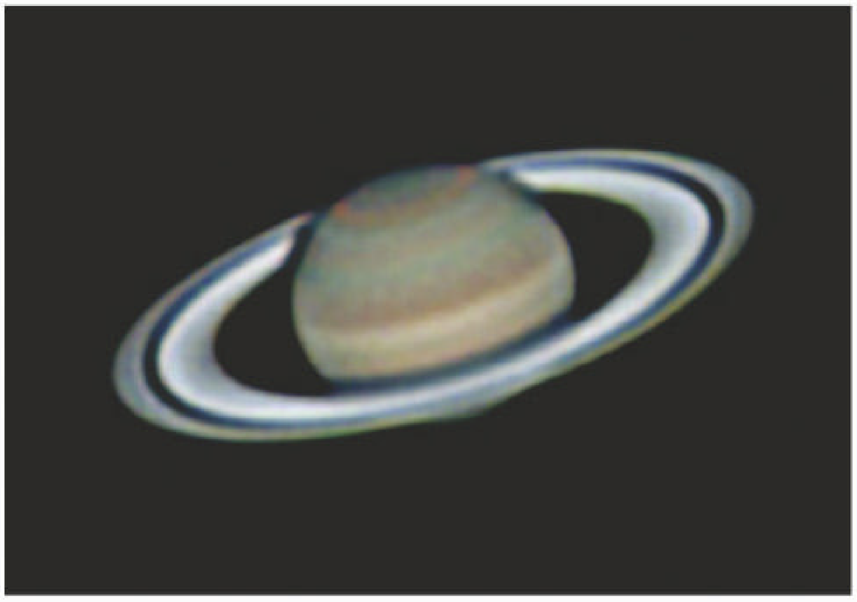
"In 2009 I tried my hand at astrophotography. It was a steep learning curve, and I went through a variety of different cameras. I'm working on duplicating some of Damian Peach's excellent planetary images."



Above: The Eagle Nebula (Messier 16)

Right: Saturn and its rings

Left: Our natural satellite's mare and craters

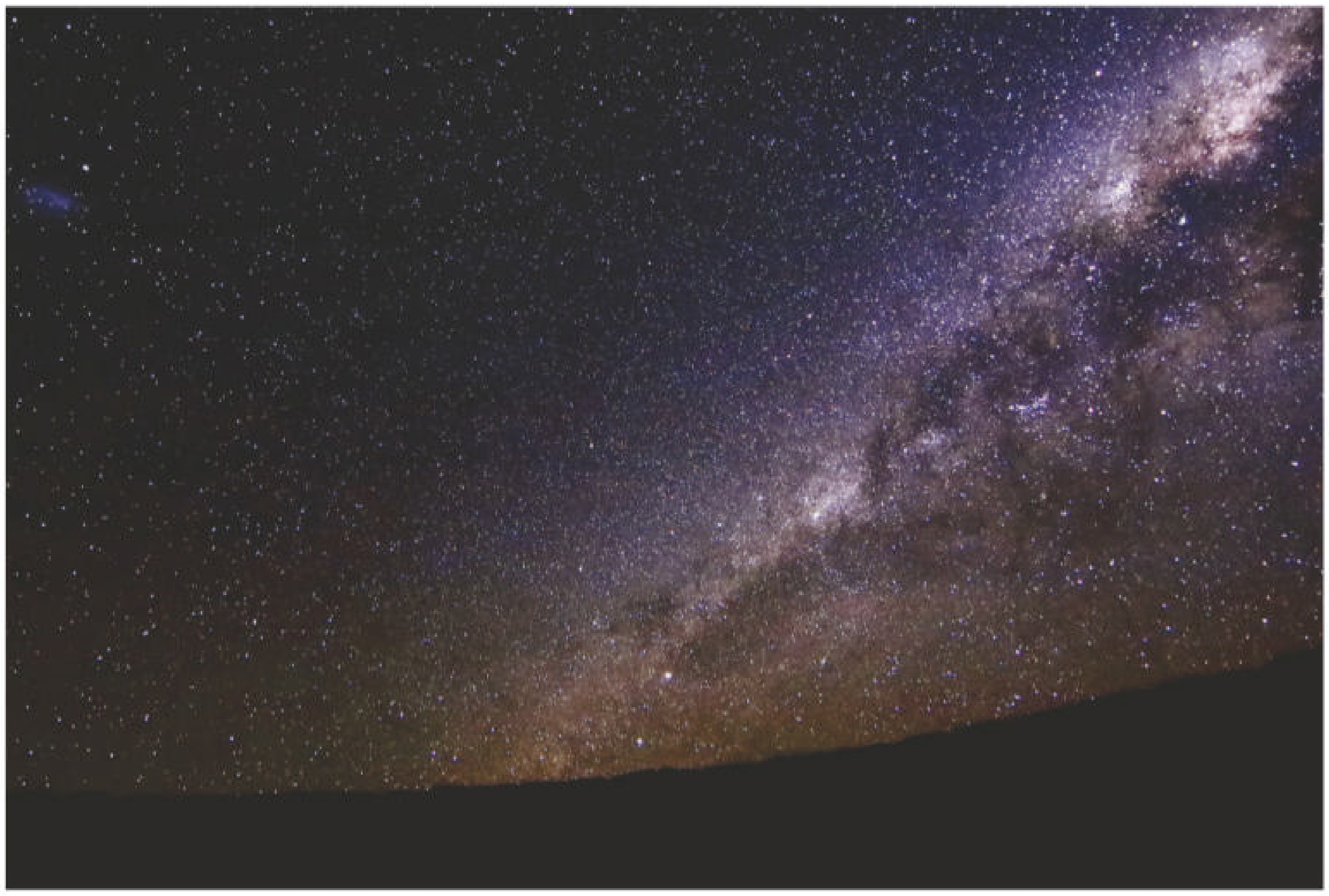


Matthew Hodgson

Location: Namibia, Africa

"My first spark of interest in astronomy manifested at age three, and by age eight, I was hooked. The obsession never left me, and my education followed a similar path, as I graduated with a master's degree in astrophysics.

"I have now been stargazing for over a quarter of a century, and while I am a passionate visual astronomer with a penchant for refractors, I have recently found great enjoyment in capturing wide-field images where a local subject can be included in the shot. This arguably allows for a more artistic composition than traditional deep-sky object astrophotography."



Right: The Milky Way

Unistellar eVscope

Great for long-exposure astrophotography, this computerised telescope provides superb views of the Solar System and bright deep-sky targets

Reviewed by Damian Peach

Telescope advice

Cost: £2,699 / $2,999
From: Unistellar Optics
Type: Reflector
Aperture: 4.5″
Focal length: 17.7″

Best for...

- Beginners and families
- High budgets
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects
- Long-exposure astrophotography

The eVscope is a completely unique product as far as telescopes go. It seeks to offer the user access to both long-exposure astrophotography and eyepiece viewing previously only within the realms of experienced amateurs with large telescopes. The telescope was developed by Unistellar in partnership with the SETI Institute, and is primarily geared towards participating in citizen science projects. With its unique features and design, this is a telescope we were particularly keen to test.

The eVscope is quite unusual in its design; unlike a standard telescope, this one uses a combination of optical and electronic imaging technology to form the image you see through its eyepiece. The secondary mirror has been replaced by a CMOS image sensor - the Sony IMX224MC. The telescope's eyepiece is also unusual in that it is an OLED display viewed through a small eyepiece-like viewer on the side of the telescope.

Power for operating the scope comes from a rechargeable lithium-ion battery that offers around ten hours of operation time - easily enough for a long observing session. The telescope also has USB ports for phone charging or for charging the telescope itself. The telescope sits on a single-arm alt-azimuth fork, which at first glance looks more than adequate for its small size. The telescope unit sits atop a sturdy, fully adjustable, lightweight aluminium tripod with integrated bubble level. When setting up, which takes just a few minutes, the whole scope is impressively lightweight, and can be moved around easily.

Lastly, but importantly, you'll need to download the Unistellar app and install it on your phone. We used a Samsung S10+ for running the app, with no issues encountered. Once that's done you are ready to get out under the stars and see what the Unistellar eVscope is capable of. Once the app is downloaded and installed, you can begin controlling the telescope. When you first open the app, it asks you to select your sky quality level to help it gauge what objects would be well suited to your sky conditions. You then need to connect to the eVscope itself via its WiFi connection. The telescope emits its own signal, which you can connect to quickly and easily. Once this is done you are ready to start observing. The app user interface is very user friendly and contains a wide variety of features. Almost 5,000 objects are available, while there is also the option to point to your own custom coordinates. The app also has other sections for transient events, comets and asteroids for those looking for more unusual targets to try their hand at.

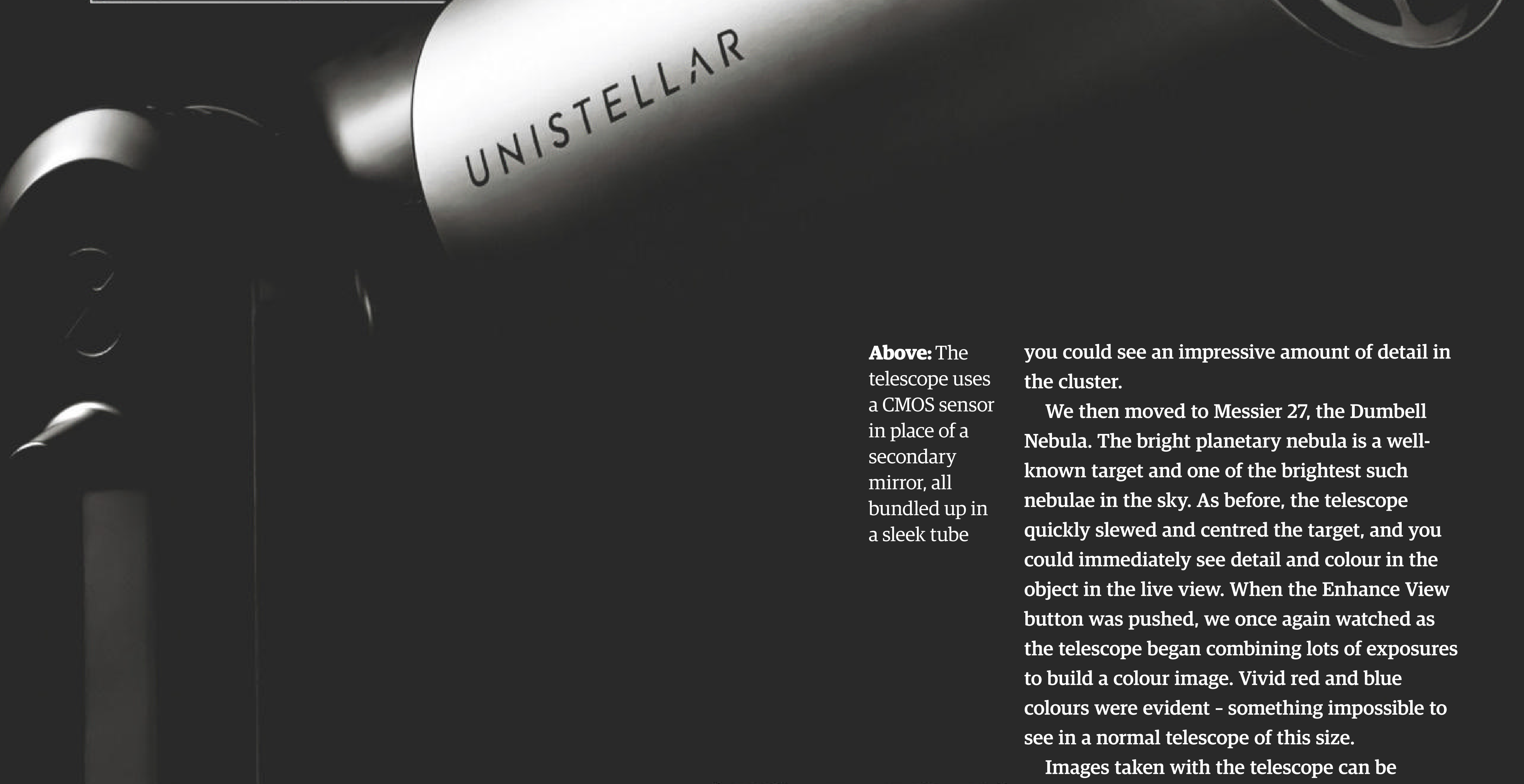
Alignment with the sky is accomplished via an automatic align procedure, completed in under a minute with just the push of a button. Our first test was actually in partly cloudy conditions, and even then it managed to achieve proper alignment. Using its clever Autonomous Field Detection software, it can automatically identify where it is pointing in the sky, even from light-polluted areas where few stars are visible. Once aligned it automatically begins tracking at sidereal rate to keep the object centred within the telescope field.

Our first test object was Messier 2 in Aquarius. We punched in the designation on our phone and clicked the slew tool command, and off the telescope went, quickly slewing to the target area. During the slew, it refines its pointing by identifying star fields close to the object to ensure your target ends up very close to the centre of the field of view. The whole slew takes around a minute, and the app notifies you when it completes. From then on you can click the Enhance View button and the telescope will begin building an image in real time, which you can watch through either the small eyepiece viewer or your phone screen.

Viewing objects directly through the eyepiece viewer is especially nice as you see the view in the way you would via a normal telescope, but in addition you quickly see details emerging in the view as the telescope takes and combines many short exposures. Even after 60 seconds

Left: The tripod is sturdy, but lightweight for portability

Messier 33



Above: The telescope uses a CMOS sensor in place of a secondary mirror, all bundled up in a sleek tube

you could see an impressive amount of detail in the cluster.

We then moved to Messier 27, the Dumbell Nebula. The bright planetary nebula is a well-known target and one of the brightest such nebulae in the sky. As before, the telescope quickly slewed and centred the target, and you could immediately see detail and colour in the object in the live view. When the Enhance View button was pushed, we once again watched as the telescope began combining lots of exposures to build a colour image. Vivid red and blue colours were evident - something impossible to see in a normal telescope of this size.

Images taken with the telescope can be automatically saved to your phone. The images themselves aren't comparable to what you would get with a dedicated high-end camera, but nonetheless the images are of good enough quality, showing plenty of colour and detail in the objects we photographed with the telescope.

Observing with the telescope is surprisingly enjoyable, and it's great fun to peer into the eyepiece viewer watching your chosen object appearing before your eyes. That said, we find it hard to understand where the Unistellar eVscope really fits into the grand scheme of telescopes and equipment available to amateur astronomers. It has a rather conflicting position. Its premium price tag puts it firmly in the category of equipment more experienced and advanced observers would be looking at, but it is likely of most benefit to those wanting to take their first steps into astrophotography.

Messier 27

NGC 891

NGC 6946

In the shops

The latest books, apps, software, tech and accessories for space and astronomy fans alike

1

3

1000-piece Jigsaw
NASA
Features imagery from the Hubble Space Telescope
For ages 14+ • Assembled size: 19.5 x 27 inches (49 x 68.6cm)
orb

2

1. For observing

Astrogloves

Cost: £19.99 (approx. $27.35)
From: astrogloves.net
Designed by UK amateur astronomer Martin Hall, these are the perfect addition to your astronomy kit bag. The semi-fingerless design - whereby your thumb and first two fingers of each hand are free - allows you to maintain control while changing eyepieces, tightening clamps and focusing your telescope on those cold winter nights. The sturdy gloves are made from durable neoprene and feature double-layer spandex backs. The palms are made from padded synthetic leather. They're available in three sizes: small, medium and large.

2. For a treat

Martins Chocolatier Luxury Chocolate Planets

Cost: £13.99 (approx. $19.10)
From: Martin's Chocolatier
Gift someone the Solar System with these luxurious handmade Belgian chocolates. Each planet and our Sun has been expertly created on Earth using 100 per cent Belgian chocolate and artisan flare. These chocolates are delightful to their very core, hosting a variety of heavenly centres: orange cream, chilli/cherry ganache, peachy cream, praline cream, caramel salt, praline, mocha cream, blueberry ganache and toffee caramel. A perfect treat for when you need to indulge in something special.

3. For fun

NASA Jigsaw Puzzle

Cost: £14.99 (approx. $20.50)
From: thumbsup.com
Create your very own window into the universe with this 1,000-piece NASA jigsaw puzzle that features stunning imagery from the Hubble Space Telescope. With three awe-inspiring images to choose from, this jigsaw will definitely keep you busy! Suitable for ages 14 and over, this jigsaw is the perfect gift for the space lover in your life. Or why not treat yourself instead? After all, we all need something to do on a cold and cloudy winter's night. Once assembled it'll make for a great decorative piece, too.

5

4

> "THIS LAMP WOULD MAKE THE PERFECT ADDITION TO YOUR HOME, CREATING A RELAXING AMBIENCE"

6

4. For school or work

Science Museum Moon landing TV lunch box

Cost: £10 (approx. $13.70)
From: Science Museum
Be the talk of the lunch table with this fun lunch box, designed to resemble a retro television set, featuring an animated cat and mouse duo on the lunar surface. The lenticular printed screen cleverly adds another dimension to your dining experience. Suitable for both adults and children, this wonderfully retro tin lunch box measures 20.5 by 19.5 by 10.0 centimetres (8.0 by 7.6 by 3.9 inches), so there's plenty of space for your sandwiches and snacks.

5. For your home

3D Moon lamp

Cost: £20.00 (approx. $27.35)
From: menkind.co.uk
View a magnificent full Moon every night with this 3D Moon lamp. Bask in the natural glow of this lunar lamp, which features three different illuminations: white light, warm light and natural light. The lamp measures approximately 13 centimetres (5.1 inches) in diameter and is mains operated. You can also take control of your viewing experience with the dimming function. Perched upon a wooden stand, this lamp would make the perfect addition to your home, creating a relaxing ambience with its soothing lustre.

6. For your home

Bloomingville MINI Rocket seagrass storage basket

Cost: £100 (approx. $136.75)
From: John Lewis
This charming basket is handwoven with environmentally friendly, fast-growing seagrass, and has been hand painted for a natural charm. With an open section on one side and a lid that lifts up for easy access, this basket is practical with a playful twist. It also boasts generous dimensions, with a height of 68.5 centimetres (27 inches) and diameter of 40 centimetres (15.7 inches). Let your imagination take flight and bring the wonders of space exploration into everyday life.

Dolores “Dee” O’Hara

NASA’s first aerospace nurse, O’Hara was instrumental in developing space nursing

O’Hara ensured that the Mercury Seven were fit and healthy for their pioneering missions

© NASA

Dee O’Hara is a pioneer in the field of space nursing. The first appointed aerospace nurse at NASA, O’Hara worked closely with astronauts from the first human spaceflight program of the United States, Project Mercury, as well as the second human spaceflight Gemini Program, the Apollo Program to the Moon and the first American space station, Skylab.

During her first assignment with the Mercury program, O’Hara’s duties included setting up the crew sleeping quarters and the examination area for the astronauts. But first and foremost she was the astronauts’ primary nurse, where she not only took care of their medical needs, but gained their trust, later building friendships that would last a lifetime.

Due to the rigorous physical examinations that the astronauts had to endure, where they were routinely poked, prodded and pricked, it was no surprise that the medics were not their favourite people. NASA therefore decided that it would be beneficial to bring a nurse onto the team, as the astronauts would be much more likely to open up and talk to a nurse rather than a flight surgeon, who had the authority to prevent them from flying. To gain their trust, O’Hara made a deal with them: “I told them I would never betray them unless, in my opinion, what they told me would jeopardise them or the mission. In that case, ethically I would have to report it to the flight surgeon. They understood that.”

O’Hara became an invaluable part of the team, with the astronauts refusing to allow anybody else to take their blood before a flight. She went on to continue to work closely with NASA astronauts and their families, witnessing every launch from the first Mercury launch through to the first Space Shuttle. “I feel fortunate to have been a part of a unique and exciting time in space history,” she said

Born 9 August 1935 in Nampa, Idaho, O’Hara had a humble upbringing. She lost her father when she was a senior in high school, and her mother worked hard to put her through education. In 1956 O’Hara graduated from the Providence Hospital School of Nursing in Portland, Oregon, before moving on to study operating room techniques at the University of Oregon. Later she worked as a surgical nurse at the University of Oregon Medical School.

One day, her roommate suggested that they should join the US Air Force and see the world. O’Hara hesitated at first, but then agreed to enrol, not realising at the time that it would be a decision that would send her on a very different path to her roommate. The Air Force sent O’Hara to the Patrick Air Force Base in Florida in May 1959, and in April 1959, the first seven astronauts for the Mercury program were selected. A mere six months after beginning her job as a staff nurse at the Patrick Air Force Base, O’Hara was offered a job as NASA’s first aerospace nurse. By 1960, O’Hara was heading to Cape Canaveral to establish the aeromed lab which would serve America’s very first spaceflight program – Project Mercury.

Though aerospace nursing remains an integral part of spaceflight, things are certainly a little different now. Nowadays the astronauts are not the responsibility of just one nurse, but several, with various medical teams supporting the astronauts before, during and after launch. Though the personal connection between nurse and astronaut has been lost somewhat, O’Hara’s modesty about her accomplishments have not: to this day she remains convinced that she was simply “in the right place at the right time”.

All About Space

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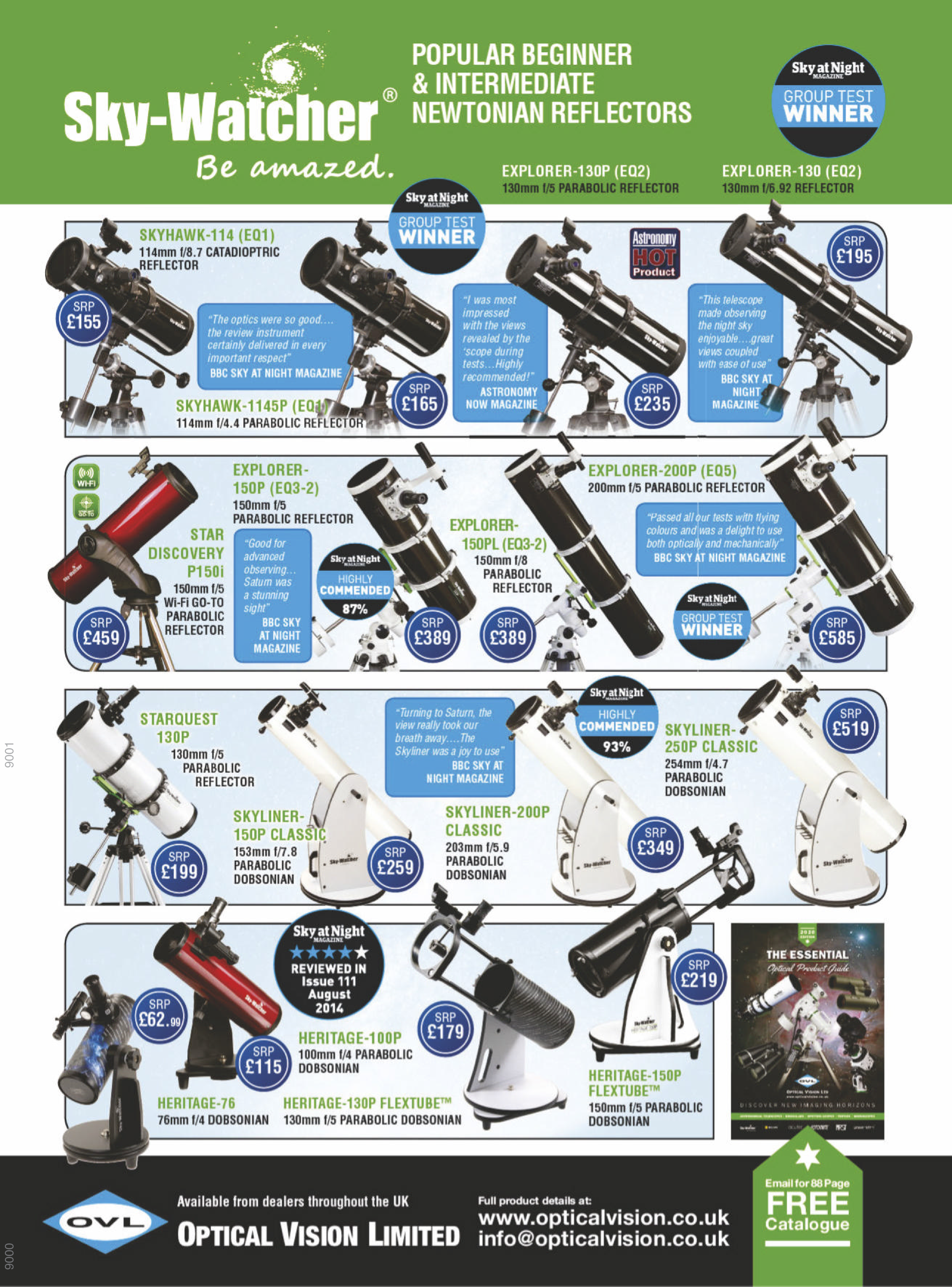

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Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 111 August 2014

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